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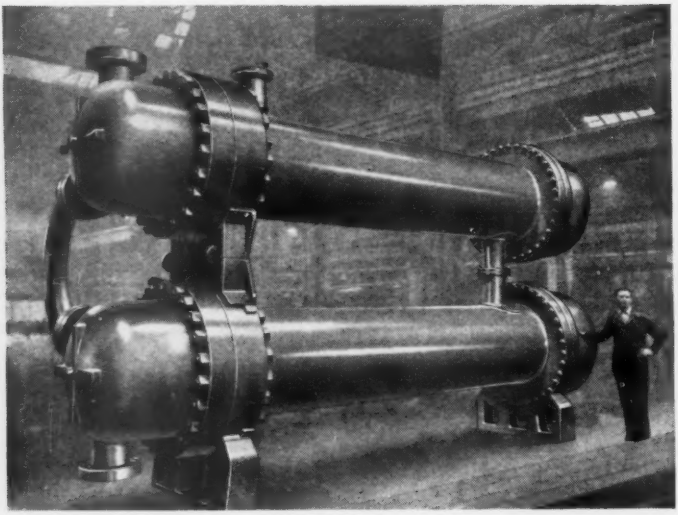

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A MESSAGE FROM THE PRESIDENT TO ALL MEMBERS OF THE INSTITUTE OF PETROLEUM

On this, the occasion of the launching of our new venture, "The Institute of Petroleum Review", I feel that not only are we adding one more to the list of successful publications of the Institute, but that we are performing a new and very special service to the Petroleum Industry.

For many years the Journal of the Institute, with its accompanying Abstracts, has been recognized as an important medium for the publication of papers dealing with the research and similar technical aspects of our Industry, but we have had, up till now, no means of covering the wider field of subjects of general interest to the Industry as a whole. To do this, it is necessary to deal in turn with all aspects of petroleum, both technical and non-technical, in a way that will appeal to the general reader and not only to the specialist. In these days, most of us can only hope to become expert in one branch of our complex Industry, but we can all benefit from a better understanding and appreciation of what our colleagues are doing in other fields. The I.P. Review, *by its articles and notes will, I feel sure, help to promote this better understanding of the Industry as a whole, and provide a means for the interchange of information and opinions to the advantage of us all.*

ANDREW AGNEW.

3rd December, 1946.

THE I.P. REVIEW

By THE HONORARY EDITOR

WITH the enlargement of the scope of the Institute of Petroleum, as represented by the change of title from Institution of Petroleum Technologists, it became evident that it was desirable to make available for our members a much more varied diet than is normally obtainable in the *Journal*.

The *Journal of the Institute* is mainly concerned with new advances in knowledge, largely as a result of research work. In consequence, many of its articles are of interest to only a proportion of the members of the Institute. The Publication Committee, however, endeavours to make sure that the wide range of interests of members, whether geological, production, transportation, refining, utilization, or economics, are represented in the papers presented at

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the Institute meetings, in order that a balance can be maintained in the *Journal*. In the Abstracts, full attention is given of all sections of petroleum technology, and an attempt is made to make the Abstracts as extensive as possible, because they are particularly valuable to overseas members, some of whom may have to rely on the Abstracts for their technical information.

Nevertheless, it has been felt for some time past that whilst the refining, utilization, and geological sides are fairly adequately covered in the *Journal*, there are not enough papers on the distribution and economics sides of the petroleum industry. This is partly due to the fact that a relatively large proportion of our members are chemists and physicists, who have more information available for publication and who have established a tradition of publication. It is, therefore, much easier to obtain articles on these subjects than, for example, on engineering aspects of the petroleum industry other than refining, although such information is particularly important to those of our members who are engaged in the distribution of petroleum products.

The Institute of Petroleum during the last thirty years has built up a strong organization of people whose primary training may lie in widely different fields, but who are linked by a common interest in the petroleum industry. Its publications must reflect all these aspects of knowledge which range from problems conerned, for example, with the free energies of hydrocarbons to the design of can and bottle fillers.

In this new publication it is hoped to provide a number of articles of not too highly a specialized character which will be of interest to all members of the Institute, no matter in what branch of the industry they may be engaged. In addition, we hope to include news of the petroleum industry in general, and in particular of developments occurring in Great Britain and in the British Commonwealth.

Much fuller information will, it is hoped, be included in the *I.P. Review*, both as regards the activities of Council and of its Committees; Council has been anxious for the last five or six years that this should be done, but it has not been possible to provide the information during wartime owing to the pressure of other activities. From the point of view of the further development of the Institute, it is imperative that such information concerning the Council and its Committees shall be available in order that, as progress is made, each step can be carefully considered by the members who are essentially the Institute of Petroleum. Amongst the news items of the industry, we hope in addition to include personal items.

As far as space allows information will be given concerning developments in industrial processes, equipment, and products, relating to the petroleum industry. It is also hoped to give a general account of meetings of other institutes and societies when they are of special interest to members of the Institute. At a later stage, we may be able to include a brief account of matters raised in Parliament which may be of special interest in connexion with petroleum, and a summary of information published by various Government Departments on petroleum matters.

It is proposed to include in each issue of the *I.P. Review* two main articles which will deal with important aspects of the petroleum industry and to select the subjects so that in the course of the year many of the principal fields of interest will be included. This means that many more papers are required for publication, and the Publication Committee would welcome suggestions from members as regards the future of the *I.P. Review*, which, by its nature as an experimental publication, must develop and may radically alter its format and method of presentation in the future.

THE ENGINE TESTING OF LUBRICANTS*

By C. D. BREWER, M.Inst.Pet.†

The paper deals with engine testing of lubricants in general terms, and discusses principally some of the mechanical factors which have a bearing on the conditions to which the lubricant under test is subjected, and how these factors may be controlled.

It is intended here to deal with the engine testing of lubricants only in general terms and to discuss principally some of the mechanical factors which have a bearing on the conditions to which the lubricant under test is subjected, and how these factors may be controlled. It is not possible, in a short paper, to deal comprehensively with all aspects of oil testing or to make more than a passing reference to specific test procedure or to the chemical work which is an essential adjunct to engine tests and which, in any case, have been the subject of many excellent papers in recent months. The following notes refer particularly to the testing of lubricants in compression ignition engines, but the principles discussed apply equally to any type of engine.

In spite of the efforts made on the part of chemists to evaluate in the laboratory the potential service behaviour of engine lubricants, it is still not possible to draw up a specification for a new and untried blend of oil which will meet with any degree of certainty all the requirements of an engine in service. It is for this reason that the internal combustion engine has been for more than twenty-five years, and still is, the most reliable and, incidentally, the only really convincing tool for the true assessment of the performance of an oil under simulated service conditions. It is not only in the testing of the finished product that it finds its place in a laboratory, but in fundamental studies of the behaviour of oils under a wide variety of conditions. The internal combustion engine is invaluable in the development of new lubricants to keep pace with engine design, to meet the ever increasing severity of engine operating conditions found in service.

For the purpose of oil testing the internal combustion engine must be considered as an instrument in which the oil is subjected to conditions of severe mechanical and chemical stress. The measure of the ability of the oil to perform satisfactorily certain specific functions is determined or interpreted from the condition after test of various parts of the apparatus, such as pistons, rings, etc.

If the engine is considered as a complex measuring instrument in which fuel and water are merely essential for its operation, its true function can best be appreciated. As with any other measuring instrument, it is necessary that the set-up and operation be conducted in a standard manner and under standard conditions for each test if accurate and reproducible results are to be expected.

With this in mind the various details of the engine which are known to play an important part in determining the performance of an oil can be examined, and how best these conditions may be controlled, can be decided.

OIL DISTRIBUTION IN A TYPICAL ENGINE

In any internal combustion engine the oil serves two main functions, to lubricate and to cool. If it were necessary only to lubricate and to maintain a continuous oil film between relatively fast moving parts and thus prevent metal to

* Paper read before Stanlow Branch, Institute of Petroleum, March 20, 1946.

† "Shell" Refining & Marketing Co. Ltd.

metal contact, the task of finding a suitable lubricant would be comparatively simple.

Unfortunately, it is as a coolant that the conditions under which it is required to function are best calculated to destroy it.

Oil is a comparatively poor conductor of heat, and in order to be effective as a coolant it must be pumped round the engine in large quantities to the various parts which must be cooled, principally the bearings and pistons. In a typical engine (Fig. 1) the oil is pumped under pressure to the bearings and from them is flung off in the form of a continuous spray

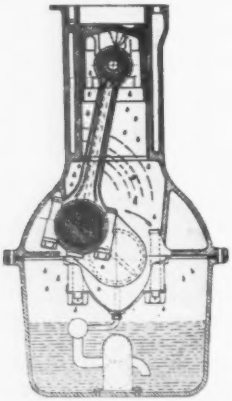

Fig. 1.—Oil distribution in a typical engine

to the cylinder walls and the under-side of the pistons, and then drains back into the sump where the heat picked up in its passage round the engine is dissipated through the walls of the crankcase to the surrounding air.

It will be apparent, therefore, that the oil is subject to considerable heat; the under-side of the piston crown may be at a temperature in excess of 200° C, and is in contact with the crankcase atmosphere containing oil in a finely divided state, conditions conducive to its breakdown. The extent to which the oil is subject to these conditions will be governed by the temperature of the hottest part with which it will come into contact and the rate of flow of the oil through the system.

Very little is known about the distribution of oil in an engine; it is very much affected by details of individual engine design. Even so, many variables are present to affect the distribution, but, fortunately, can be subject to some measure of control. The quantity of oil flung from the crankshaft on to the under-side of the piston and the cylinder walls in the form of spray, the distribution of the oil throughout the engine and consequently the rate of circulation of the oil in the system, is controlled by the oil pressure and viscosity, engine speed, bearing clearances, and the surface finish of the working parts. It has been shown, for instance, that an increase of one-thousandth of an inch in the running clearance of a connecting rod bearing can alter the quantity of oil flung off from this bearing by as much 100 per cent. The oil distribution over the working surface of the pistons, rings, and cylinder bores is affected to a considerable extent by the condition of the wearing surfaces of these parts, which in turn control oil consumption and wear, and to some extent, piston temperatures. Control of oil consumption by adjustment of oil pressure to the bearings will change the oil distribution in the crankcase, and the rate of oil flow throughout the system occasioned thereby affects the conditions to which the lubricant is exposed.

Without seeking any further for factors which may affect the treatment to which an oil is subjected, it can be shown that in a typical engine there are a number which must be controlled before a test can be expected to give a truthful indication of the oil's performance. Unfortunately, this is not quite so simple as might at first be supposed, as these factors are interdependent and adjustment to one may affect others to an

unpredictable extent. It is interesting, however, to analyze these factors individually to see how control may best be applied.

CONTROL OF MECHANICAL FACTORS AFFECTING PERFORMANCE

It is essential that in any laboratory test procedure the dimensions and surface finish of the pistons, rings, cylinder liners, and bearings, etc., be controlled to the closest practical limits. In the production of such parts, as in all machining work, tolerances in dimensions and surface finish must be permitted and are governed somewhat by the material from which they are made and the tools used in their manufacture. In production type engines the tolerances of replacement parts are governed by economic considerations, but for laboratory work it is usually possible by the careful selection of spares from maker's stocks, to reduce the tolerances to acceptable limits. It is fortunate, however, that most if not all these parts can be obtained from firms specializing in their manufacture, who, because they are specialists, are able to work to much closer tolerances than would be economically possible to the average engine builder. Since tolerances in limits or materials must be expected however carefully consumable parts are produced, it is always good practice to acquire such parts in batches of sufficient quantity to cover the requirements of any single series of experiments.

The piston ring is a deceptively simple component, but its characteristics are very difficult to assess and reproduce. Its function is to avoid loss of combustion pressure through leakage of combustion gases into the crankcase; blow-by gases leaking past the piston rings from the combustion chamber contain the products of combustion which cause contamination of the oil by condensed water, soot, and heavy ends of the fuel, or products of partial combustion of the fuel. The rings have also to convey most of the heat from the piston to the cylinder walls, and control oil consumption and the flow of lubricant over the piston surfaces.

Every one of these factors has a bearing on the conditions to which the oil under test is subjected, and variations in any one of them from test to test may affect the apparent performance of the lubricant. Rings must therefore be specially selected for dimensions, free gap, closing pressure, and butt clearance in a standard bore. The finish of the side faces is usually prepared in the laboratory by lapping to a set and carefully executed procedure. The diametral face may be lapped, ground, or turned, according to the type of test being conducted. The side clearances of the rings in their grooves must be controlled to very fine limits, and the desired clearance may be obtained by selection or, more conveniently, by lapping, since this is already included in the preparation of the ring.

Although the dimensions of the ring determine the pressure it exerts against the cylinder wall, it is essential, in precision work, such as the study of wear or oil consumption, to determine the polar diagram, the pattern of the ring pressure round its circumference. Owing, however, to the difficulty of measuring accurately the pressure at any point and the time involved in so doing, it is usual, in routine tests, to rely upon the control of dimensions.

The piston must be similarly treated for dimensions and finish, the working faces of the ring grooves and the piston skirt, and the clearances of the ring lands being the principal features receiving attention.

There are several features of the cylinder block which are of interest, and which are a particular problem in the testing of lubricants (Fig. 2). In its simplest form the cylinder barrel is cast integral with the water jacket, and in casting it is

very difficult, if not impossible, to ensure an even or uniform thickness of wall between the bore and the water in the jacket. As the temperature of the surface of the bore and, incidentally, that of the piston and rings, is dependent on this thickness it must be controlled. This is of particular importance where several engines are engaged on a single study or where several cylinder blocks are used in succession on a particular

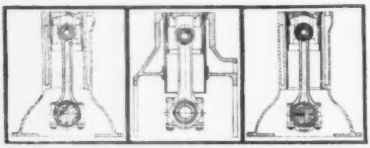

Fig. 2.—Types of cylinder block—plain, wet liner and dry liner

unit. Another factor affecting the rate of heat transfer from the cylinder wall to the cooling medium and, therefore, the surface temperature of the bore, is the presence of scale in the jacket. It is, therefore, advisable to treat the inside of the jackets with a descaling fluid to ensure that any deposits which may have been formed during a previous run are removed before each test. A simple and effective remedy for the potential difficulties of control of the cylinder bore temperatures is by the use of engines designed to accommodate "wet liners". Liners of this type may be machined all over so that the wall thickness can be held to close tolerances, and uniformity between cylinders is ensured. The replacement of a wet liner is the matter of only a few minutes and is relatively inexpensive. The use of a "dry-liner" with which some engines are fitted is to be discouraged in engines used for laboratory purposes. Errors in wall thickness as in the case where the barrel is cast integral with the block still obtain, and the temperature of the surface of the bore is additionally dependent upon the rate of heat transfer through the contact surfaces of the liner and the block, which is in turn affected by the fit of the liner in the block and by the surface finish of the outside of the liner and the bore into which it is fitted. This type of liner is also subject to distortion and re-fitting calls for special tools and machine shop service if it is to be carried out with any chance of success.

Ideally, each test should be started with a complete set of wearing parts specially selected for tolerances and finish and, in fact, where extreme accuracy is required, such as the final assessment of an oil's performance, this is the usual practice. In some types of routine tests, however, experience has shown that some conditions with respect to clearances and finish may be modified and limits for allowable wear, say, for cylinder bores, adopted such that a reasonably useful life of the wearing parts may be expected. In certain tests, lack of reproducible results leads one to believe that even the closest tolerances obtainable leave much to be desired.

THE CHOICE OF TEST ENGINE

The objects of testing lubricants in engines are two-fold. Firstly, experimental, for the study of the characteristics of the oil and for the development of new blends. Secondly, the assessment of field performance of an oil under simulated service conditions.

From the nature of the tests, therefore, there need be no doubt as to the most desirable type of unit to be employed under each heading. In experimental and development work, and in order that the factors already discussed and which are known to affect the behaviour of the oil may be best controlled, the test unit should be as simple as possible. It will, by implication, be a single cylinder unit in which all working parts which must be subject to close control for dimensions and surface finish are readily accessible and easy to replace

(Fig. 3). The piston assembly and the cylinder barrel are perhaps the most important items in an engine devoted

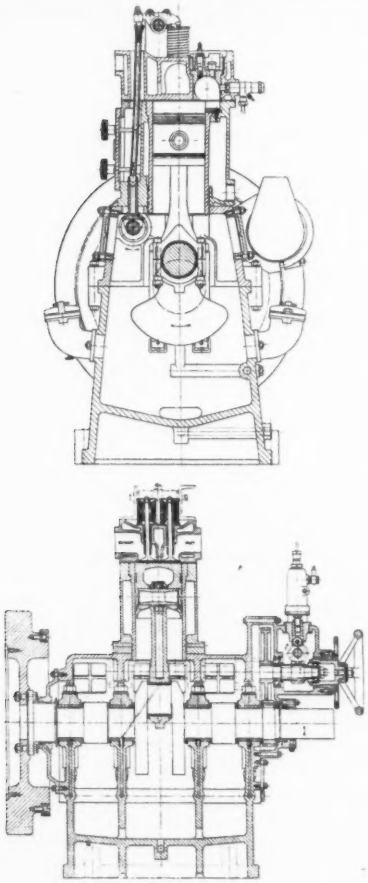

Fig. 3.—Sectional views of laboratory test engine (Fowler)

to the testing of lubricants, and it is therefore necessary that the design of the top half of the engine be such as to give easy access to these parts. This condition is adequately met if the test unit is fitted with a detachable cylinder block, a fact which will be appreciated immediately by all who are concerned with the operation of experimental units. The advantages of an engine so designed are obvious and numerous. Perhaps the greatest advantage is that the piston may be removed with a minimum disturbance of engine parts, particularly the connecting rod bearings, merely by lifting the block and removing the gudgeon pin. It is not necessary to fumble about inside the restricted space of a hot crankcase to undo connecting rod bolts, and the operation of removing the piston can be accomplished in the matter of a few minutes if the unit is properly designed. Servicing of the cylinder barrel is greatly facilitated either by fitting a new wet liner, if it is so designed, or by the preparation of spare blocks either by re-sleeving or re-honing.

The main requirements of the lower half of the engine are that the crankshaft and bearings be of ample proportions to give long periods of operation without the necessity of servicing and having regard to the necessity of maintaining constant bearing clearances as far as possible. In this respect, it is an advantage to use a hardened crankcase to reduce wear to a minimum; a hardened crankpin is essential if alloy bearings of the copper-lead type are used as, for instance, in the study of corrosion. The sump and crankcase should be so constructed that they are free of webs and pockets, and thus facilitate easy and complete drainage of the test oil.

The design of the experimental engine as a whole must be sufficiently flexible to permit the widest possible range of test conditions. It must, therefore, be very robust, and have an operating capacity such as will subject the oil to conditions more severe than are likely to be found in service since, by the very nature of its application, experimental tests are frequently conducted under accelerated conditions. Provided that the general requirements

outlined are met, it is only a matter of ingenuity and a good workshop to adjust the set-up and develop a test procedure for any desired investigation.

From the foregoing, it might be concluded that the industrial single-cylinder unit would find no place in the laboratory. However, although it is seldom that the majority of these requirements are found in such a unit the reverse is actually the case as the industrial unit forms by far the greater bulk of engines found in such laboratories, but it is

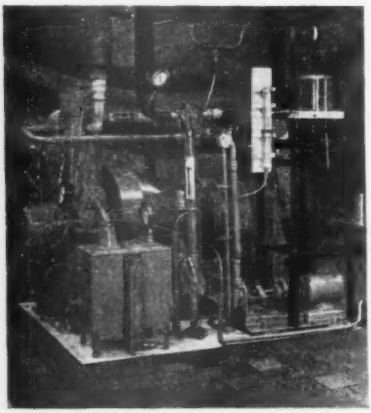

Fig. 4.—Test set-up of National engine

doubtful if the engine manufacturer would recognize his own offspring after an experimenter has adapted it to his own purpose (Fig. 4).

In the second class of engine testing, where the object is to correlate as nearly as possible with results obtained in the field on the finished product, the single-cylinder unit is in itself not wholly satisfactory. In any case, tests conducted in multi-cylinder engines are unquestionably more convincing, and it is easier to simulate field conditions on engines possessing the same general characteristics as those used in service. Although constant and controlled operating conditions are not so easily obtained in a multi-cylinder engine with the same degree of precision as is possible in the single cylinder unit, it is questionable if such precise control of these factors is of very great importance, since in practice the production engine is built and operated with much wider limits than would be tolerated in the laboratory.

It is not possible to assess the full performance of an oil in any one unit as individual designs have their own particular idiosyncrasies in respect of their behaviour towards the lubricant. It is usual, therefore, to conduct such tests in several engines in which significant characteristics such as ring-sticking, lacquering, bearing corrosion, etc., predominate. The standard procedure adopted by the U.S. Army and Navy for the acceptance testing of oils for service use is a good example of this wherein four types of engines are used, in each of which is determined a particular aspect of the performance of the oil.

The value of a test is as dependent upon the care taken in the preparation of the unit as it is upon the control of test conditions and the accurate interpretation of the results obtained. In the preparation of an engine the one golden rule is absolute cleanliness, not only of the various parts as they are assembled, but of the complete unit. Judged by the amount of adventitious matter that is removed from the engine by flushing out prior to a test, it is not by any means an easy condition to fulfil. In this respect, as we have already observed, the design of the unit is important, particularly with regard to the crankcase which must have an interior free of webs and pockets in which dust and solid matter from previous tests can lodge.

Before assembling the engine, all critical components such as pistons, piston rings, liners and bearings must be carefully inspected to ensure that they are in all respects within the permissible tolerances dictated by the nature of the test, and great care must be

exercised during assembly to see that these parts are in no way damaged in the process. This is particularly important in the case of piston rings where faulty handling or overstressing during fitting can alter characteristics to an alarming extent.

After assembly the test unit is usually broken-in by running to a definite schedule of speed and load gradations. The oil used for the break-in is usually one which is the main component of the blend to be tested subsequently. After break-in the oil is drained and the crankcase re-charged with the oil to be tested. Alternatively, in order to avoid further any possible contamination of the test oil, particularly if its base stock is not known, the last section of the break-in is run on the oil to be tested, and the oil changed again before the commencement of the test. It is an excellent practice to take an oil sample as soon as correct operating conditions are reached in the test proper, in order to determine by chemical analysis the presence, or otherwise, of insolubles or dilution as possible results of faulty preparation.

TEST PROCEDURES

The design of the test procedure will be determined by the principal objective. This may be to assess the general performance of an oil to meet satisfactorily those conditions found in service, or to study the behaviour of the oil in respect of a particular characteristic such as ring sticking, oxidation stability, etc.

In the first-mentioned category it might be supposed that in order to assess fully the field performance of an oil, it would be necessary to conduct tests of all types of engines found in service. However, experience has shown that if these tests are conducted in three or four engines in which collectively manifestations of particular phases of oil deterioration such as ring sticking, piston lacquering, bearing corrosion, etc., occur, an oil that will meet the requirements of these engines will generally be satisfactory in all engines in the field.

The problem then is to determine the conditions under which these various units are to be run and to select those conditions for each engine, which are judged best to emphasize the particular phase of oil deterioration applicable to it.

The treatment to which an oil is subjected in an engine is controlled apart from any peculiarities of the individual engine design, principally by the speed of rotation, the rate of fuel input, the temperature of the coolant and of the oil in the crankcase. All are factors which effect the 'heat stressing' of the oil.

The remaining factor, that of duration, is determined by experiment, and some guidance may be obtained from the engine maker's recommendations for crankcase drainage periods and top overhaul schedules. In order to give a fair indication of the behaviour of the oil in service, the tests must of necessity be rather long, but not so long as to be jeopardized by premature mechanical failure, such as may be caused by the breaking up of bearings or the sticking and blowing of the valves. It should be borne in mind that for convenience this type of test is usually run continuously at near the maximum capacity of the unit, a condition which is much more severe on the engine mechanically than the variable loads and speeds found in service. Tests of this type may run for periods of from 500 to 1000 hours.

As the object of these tests is to simulate service performance, the test conditions must be selected from and be at least equivalent to the worst conditions under which each engine type is expected to operate in the field.

A good illustration of this type of test is in the series already quoted, as used by the U.S. Army and Navy for the acceptance testing of engine lubricants.

Here each of the four engines used is representative of a class and all differ considerably in design, service application and operating conditions. The test conditions adopted simulate those found in service for each type, except that they are more severe than would normally be experienced.

The foregoing remarks refer to set test schedules which are used to determine the suitability of an oil for general service and are required to meet a definite minimum standard of performance. In fact, they are "go" or "no go" tests and as such give no indication of the absolute performance of the oil. This applies more particularly to oils which are outstandingly good. In order to obtain more data as to their relative behaviour, it is necessary to submit them to even more severe conditions. This may be done either by increasing the load, speed or temperature, where these are not already limited by mechanical factors, or by increasing the duration of the test. Alternatively, it may, in certain circumstances, be sufficient only to eliminate the oil change which is usually scheduled at regular intervals throughout the test.

In all tests under this heading, chemical analyses of the oil are conducted throughout the run in addition to the examination of the engine parts upon its conclusion. Oil samples are taken at regular intervals and examined for evidence of deterioration. A graph showing the increase in the sulphated ash, neutralization and saponification values, viscosity, oil insolubles, etc., plotted against the hours run gives a very fair indication of the stability of the oil, and is very useful in comparing oils whose performance judged by the condition of the engine parts is apparently similar.

Tests to determine the specific characteristics of an oil may be much shorter than those for general performance and are usually conducted under accelerated conditions more severe than are likely to be found in any form of normal service. Under this heading may be listed ring sticking, oxidation stability, bearing corrosion, etc. In this short paper it will not be possible to discuss in detail all tests of this character, but a few brief notes on the three that have been mentioned may be of interest.

Ring Sticking

For the determination of anti-ring-sticking properties of an oil, test conditions are chosen such that ring sticking may occur on any oil within a reasonable

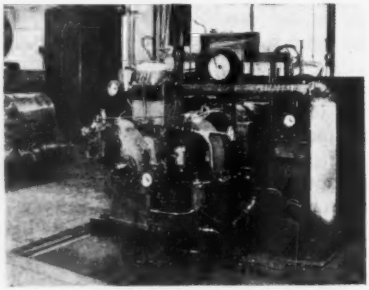

Fig. 5.—Test set-up of ring sticking engine (Fowler)

time, say, ten to twenty hours. Ring sticking is caused by the build-up of oil deterioration products behind and above the piston rings in their grooves. The rate at which these deposits form and, therefore, the time required for the ring to stick is dependent upon the temperature of the ring. Since the aim of the engine designer is to develop a piston assembly where conditions of heat flow are such that in no part of the ring groove does the temperature approach the critical value, about 250°C, under normal operating conditions and with as wide a margin of overload as possible, it is frequently difficult with a standard engine to obtain conditions that will give rise to ring sticking in a reasonable time. It is therefore necessary to re-design the piston and ring layout so

that the necessary temperatures may be obtained within the safe load capacity of the engine. The procedure then is to determine test conditions which will cause one of the pressure rings to stick in approximately fifteen to twenty hours when run on an oil known to have good anti-ring-sticking

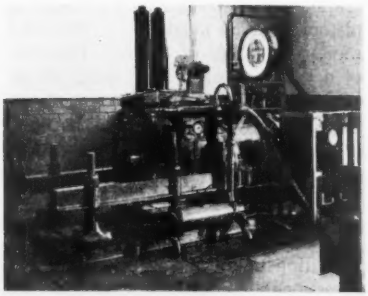

Fig. 6.—Test set-up of G.M.C. (Port blocking)

properties. The oil so chosen is used subsequently as the "top reference oil". The test is then repeated under the same conditions but using a straight mineral oil of known composition, and the time required for the ring to stick determined. This oil, called the "low reference oil", is used subsequently with the 'high reference oil' to check the performance of the engine. Having determined the length of run, termed the "duration", of two known oils of widely differing performance, other oils of unknown performance can be rated with respect to these two standards. A special type of engine adapted for ring-sticking tests is shown in Fig. 5.

Oxidation Stability and Corrosion

Bearing corrosion is due to oxidation of the oil and it is sometimes convenient to combine oxidation stability and corrosion tests.

Fig. 6 shows a typical set-up for the study of oxidation and bearing corrosion. The engine illustrated is a four-cylinder two-stroke engine of General Motors manufacture, designated type 4-71, and is an example of one of the four engines used for the acceptance testing of lubricants for the U.S. Army and Navy.

Oxidation stability is judged by the presence or otherwise of lacquer and other deposits on the pistons and engine parts, and by the chemical analysis of the oil during and after test. Corrosivity is determined by the loss of weight of the copper-lead bearings, which are weighed before and after test. The test procedure adopted for this unit is based on that used by the U.S. Army and Navy, and is of considerable severity with respect to speed and load. The duration of the test is 500 hours and the oil in the crankcase is not changed throughout this time.

ASSESSMENT OF RESULTS

A feature common to all engine tests is the attempt to break down the oil, and the measure of its resistance to the

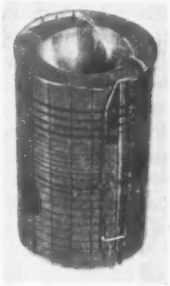

Fig. 7.—Piston with graticule for estimating distribution of deposits

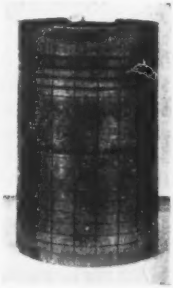

Fig. 8.—Piston after test with graticule for estimating distribution of deposits

severe treatment it receives is determined by the extent to which decomposition occurs during the test.

Decomposition is usually manifest by the formation of oil soluble and insoluble products which by precipitation on the engine parts may interfere

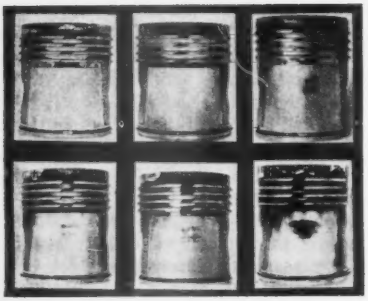

Fig. 9.—Photographic record of a series of test results

with proper functioning of the engine as a whole. Such decomposition and deposits will occur to the greatest extent where the temperatures to which the oil is subjected are highest, i.e., the piston assembly, and it is for this reason that the condition of the piston after test is taken as a primary indication of the performance of an oil.

In testing a series of oils of widely varying performance, it is possible with reasonable accuracy to rate them in order of merit by visual observation of the condition of the piston after test. However, if the oils to be tested are of nearly similar performance, rating by direct visual observation becomes more difficult and often a matter of opinion. It is then necessary to employ more elaborate methods in determining accurately the extent and nature of the deposits.

A simple method of estimating the quantity and disposition of deposits is shown in Figs. 7 and 8. After test the piston is first washed in petroleum ether to remove surplus oil adhering to the surface. A celluloid grid divided into the principal sections of the piston, such as, top land, ring land, skirt, etc., is then wrapped round the skirt, and the amount of deposits in each section estimated visually. The approximate thickness and colour, judged by comparison with a standard colour chart, is also recorded. By this means it is possible to compare the performance of any oils not only with respect to deposits, but also in respect of colour thickness and distribution as well. From the information obtained the various oils may be rated numerically.

In addition to these ratings photographic records (Fig. 9) are made of all pistons, and are invaluable in making a rapid assessment of the relative merits of a series of oils. In making photographic records it is very important that the conditions under which they are produced are closely controlled so that all photographs may be truly comparable.

The behaviour of an oil cannot, of course, be determined solely from the condition of the piston, but for a first assessment it does give a reliable indication of the probable overall performance of the oil and enables a preliminary sorting out of obviously unsatisfactory oils to be made.

LABORATORY LAY-OUT

Figs. 10 to 12 show a small section of a laboratory devoted to the development and testing of engine lubricants.

In Fig. 10 can be seen the general layout of the single-cylinder engine section of the laboratory, showing four of the five beds installed. The engines shown, reading from left to right, are,

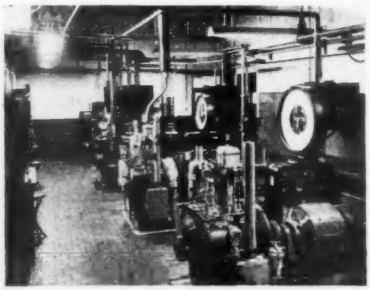

Fig. 10.—Single-cylinder engines in the laboratory

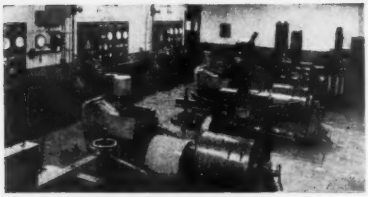

Fig. 11.—Multi-cylinder engines in the laboratory

Gardner single-cylinder, National single-cylinder (see Fig. 4), and two Caterpillar single-cylinder units of the type used for the acceptance testing of lubricating oils for the U.S. Army and Navy. The fifth bed is being installed with a six-cylinder two-stroke engine representing a type which will become prominent in the post-war market.

Figs. 11 and 12 show general views of the multi-cylinder or high-speed section, in which three of the four engines installed are of the automotive type used specifically for the study of motor lubricants. The engine on bed No. 4 is used specifically for the study of ring sticking and is shown in Fig. 5.

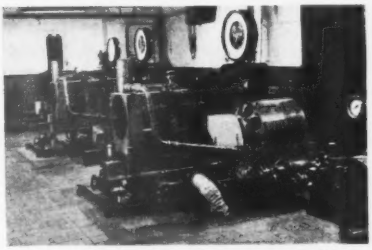

Fig. 12.—Multi-cylinder engines in the laboratory

COUNCIL COMMENTARY

In the July, 1946, issue of the *Journal* there appeared under "Institute Notes" an article entitled "A Year of Council".

In that article the functions of the Council of the Institute were outlined and a short account was given of matters that were dealt with during the preceding year. Considerable discussion has taken place as to how best to meet the desire of members to be informed of the general activities of Council without the actual circulation of minutes, which would be undesirable and of limited informative value. It has been decided that this contact between Council and members can best be maintained by the publication in the new *I.P. Review* of periodical reports in which can be given the general trend of affairs dealt with by Council.

As stated in the July article, a very great deal of the detailed work of the Council is carried on by Committees much of whose work is of a routine and unspectacular character. For example, the work carried out by Standardization and Abstract Committees constitutes a very real contribution to the usefulness of the Institute, and the Abstracts Section of our *Journal* already has a very high reputation; yet any attempt to report in detail the proceedings of an Abstracts Committee would be futile.

There are, however, from time to time issues which take the limelight and, for this reason, attention will be directed to the separate activities as they acquire what might be called "topical interest".

There are three such issues at present engaging the attention of Council through its various Committees. They might be briefly described as questions of "home", of "membership", and of "publications".

Dealing first with our home, which is the concern of the House Committee: we are installed rather inadequately in Manson House as a prolonged temporary solution of a problem created by our war-time evictment from the Adelphi

and, like most temporary solutions, this one is very far from the perfect answer to our many pressing questions of accommodation. The enhanced post-war activity envisaged and indeed, already begun, has resulted in increases in the staff and has rendered still more acute the already considerable congestion in the Manson House premises. For over a year the House Committee has been quietly, but busily, engaged in trying to find a way out of our difficulty —not necessarily out of our building— but as such negotiations have, of necessity, to be conducted with speed, verve and silence, not much can be said in public at this stage, except that the House Committee is by no means despairing of finding a solution and that we ordinary members will just have to wait and see.

Secondly, membership: our membership now stands at about 2,000. This is encouraging but not by any means the limit, and we must look to the enrolling of many more members if we are to retain and strengthen our position in the oil world and in the general community.

By our amended Constitution and still further revised By-Laws (the latter just sanctioned by Council for submission to the membership) it is sought to enrol much more heavily in the class of membership whose interests are are in the main non-technical. A special Committee has laboured long and arduously to find a satisfactory solution to this very real problem. When in 1938 the Institute changed its name from "Institution of Petroleum Technologists" to the "Institute of Petroleum", it was with the clear recognition that technologists had no monopoly of interest in the petroleum industry and that, if the Institute was to be really representative, it would need to enrol many who would not be eligible under its original terms of entry when we were a purely technological Institute. It was recognized then, and still is, that there was also need to safeguard the professional status of the technologist and the technical standing of the Institute. These dual, but not necessarily conflicting requirements, have been catered for in the latest proposals that there shall be two definite classes of membership representing the two types of interest.

On the technical side advancement would be via a new grade of Associate Fellowship to the Senior Grade of Fellowship. On the non-technical side advancement would be via Associate Membership to the Senior Grade of Membership, there being no suggestion that either the technical or non-technical classes are superior in status in the eyes of the Institute. It is hoped that this new clear alignment will result in much larger membership in the non-technical grades, thus adjusting a balance which is as yet heavily in favour of the technologist as a natural result of the fact that, prior to the change of name, the Institute was composed entirely of technologists.

Many of the Committees have been successfully enlarged to achieve this balance of interest and this applies in particular to the Publications Committee which will now be dealt with.

Thirdly, publications: the outstanding new activity of Publications is, of course, the *I.P. Review* and, although its origin and intentions are dealt with in the editorial, it may not be out of place to say here that it is an attempt on the part of Council to satisfy the expressed desire of members for what was originally asked for as "a brighter Journal". It was soon obvious that the general tone and highly technical character of the *Journal* could not be altered without meeting very grave difficulties, and this new publication was considered to be the answer by the Special Committee which investigated this problem.

The Publications Committee is probably the Committee with the most comprehensive Terms of Reference of any committee, as is indeed natural con-

sidering the large part of the Institute's activities which is concerned with publication. It naturally functions through many Sub-Committees co-ordinated under the Chairmanship of Professor F. H. Garner and his new Assistant Honorary Editor, Dr. E. B. Evans. One of these Sub-Committees is a Papers Sub-Committee, dealing with the collection of material for meetings and for the *Journal*, and the *I.P. Review*, and it is satisfactory to record that this Committee is looking well ahead of immediate requirements.

Another important Sub-Committee of the Publications Committee is the Library Committee. Yes, there is a library as well as a Committee, and its temporary eclipse is an unfortunate but unavoidable legacy of derangements caused by recent hostilities!

As most members are aware, we were hardly ensconced in spacious and dignified premises at the Adelphi before war and requisitioning turned us out and the library remained behind, neatly boarded up and inaccessible except by total removal, which has fortunately now been accomplished.

The Council Room at Manson House looks daily more and more like a book-shop, as the shelving extends and the housing of the various books and periodicals is accomplished. It is under consideration that this not by any means satisfactory half-way house will soon be replaced by something better, probably including the services of a librarian and a general strengthening of the position, until the library can function as it should and the library room become a place which members can use for reference in addition to having facilities for borrowing.

This matter is, of course, tied up with the general lack of accommodation and cannot be dealt with in a really satisfactory way until the larger problem is solved.

Election to Council: Another item looming up on the near horizon is the election of Council members to fill vacancies caused by annual retirement of one-third of the elected members. Although included under "Council Commentary", this is a matter which concerns members, who are exhorted to exercise their basic right and duty as corporate members to record their vote and thus help to maintain a state of mutual confidence between the membership and the Council members as their truly elected representatives.

Other Committees: The work of Awards, Benevolent, Branches, Education, Election, Engineering, Finance, Research, and Standardization committees calls for comment at intervals and will be dealt with in future issues, as also from time to time will reports from Institute representatives on scientific bodies.

It will be a matter of interest to the general membership that the Institute is represented on the following scientific bodies: Parliamentary and Scientific Committee, Empire Council of Mining and Metallurgical Institutions, Institute of Fuel, British National Committee of the World Power Conference, Ramsay Memorial Committee, A.S.L.I.B. and B.S.I.B., Permanent Council of the World Petroleum Congress, the National Committee for Chemistry of The Royal Society, A.S.T.M. D-2 Committee, and also more than sixty B.S.I. Committees.

This purposely incomplete account of Council activities at the moment may serve to give members at least a partial answer to the question often present, particularly in the minds of new members, i.e., "What Does the Council Do, Anyway?"

PETROLEUM AS A CHEMICAL INDUSTRY*

By DR. GUSTAV EGLOFF †

WE are in an industry which has gone through a revolution in the past seven years. Much fundamental research and development was conducted before the war but few of the processes evolved were ready for industrialization because we had no motors in our automobiles or aeroplanes to utilize the quality of gasolines which could have been made available. The war rapidly advanced from laboratory to commercial scale many processes that would normally have taken ten or perhaps twenty years to develop for producing the 100-plus octane fuel required by modern aviation motors. What we have learned in the past seven years about improving the quality of lubricating oils is a saga in itself. Processes such as catalytic cracking, not one process, but five processes, all stepped into the breach to supply the demand for 100-plus aviation gasoline. The intake of gas oil by catalytic cracking plants jumped from a low volume to over 1,000,000 barrels per day during the war and units now being installed will bring the figure to over 1,250,000 barrels. Largely because of the grounding of thousands of fighting, bombing and transport planes which did such a magnificent job in the war effort, much of this volume of gas oil will now be converted to produce motor fuel for ground vehicles.

The five processes are:

(1) the Fluid Flow catalytic cracking;
(2) the Moving Bed (known as the T.C.C. or Thermofor Catalytic Cracking);
(3) the Static Bed catalytic cracking;
(4) Cycloversion;
(5) Suspensoid catalytic cracking.

* Paper read before Stanlow Branch, Institute of Petroleum, Aug. 16, 1946.
† Universal Oil Products Co.

FLUID FLOW PROCESS

In the Fluid Flow process solid particles of catalyst in a fine state of subdivision are carried along by vaporized gas oil into a reaction chamber where temperature conditions of 850° to 1,000°F are maintained. Pressures are atmospheric or slightly superatmospheric. Some of the Fluid Flow process units process over 20,000 barrels a day of gas oil; others that are being installed will be capable of charging over 30,000 barrels per day. The Fluid Flow process is extremely interesting and important; not only is it used to produce aviation and motor fuel, but it is also being used in connection with processes for manufacturing chemicals. Most of the catalytic cracking plants at the moment are using a synthetic alumina-silica catalyst; others utilize clay activated by acid treatment, as catalyst. These catalysts may be used as comminuted powder or as microspherical particles of equivalent average diameter.

The operation of the Fluid Flow process is briefly as follows:

Vaporized gas oil conveys a stream of downflowing catalyst into a reaction chamber, where the temperatures referred to earlier are maintained. Gas, gasoline, cycle oil, diesel oil and household burning oil, but no asphaltic residue, are produced. The cracked gases consist of paraffins and olefins, mainly *iso*butane, *n*-butane, propane, and the corresponding butylenes and propylene, as well as methane and ethane. As the reaction proceeds, the catalyst becomes covered with a carbonaceous deposit, which renders it inactive. The vapours are separated from the catalyst in the reactor from which the catalyst overflows, meeting a stream of steam to distil out entrained hydro-

carbons, and then enter the catalyst regenerating chamber, where a stream of air moving in the opposite direction burns off the carbonaceous material. The regenerated catalyst flows down a leg, from which the supply for the reactor is drawn. There are no moving parts whatsoever. The solid is carried around by the force of the flowing vapours and gases. The bulk of the cracking installations in the United States and elsewhere are using the Fluid Flow process of operation.

The schematic flow in a modern type of fluid catalytic cracking plant designed to operate at daily charging rates of 10,000 to 20,000 barrels is shown in Fig. 1. A gas oil charge is passed through a heater and a portion of the charge passes through the bottom of a slurry settler where it picks up hot catalyst and by-passes the heater. The pre-heated charge conveys regenerated catalyst through a reactor riser into a reactor containing perforated baffles. Gases and vapours from the reactor pass through a separator which returns catalyst and thence to a fractionating column for the production of gasoline and both intermediate light and heavy oils and column bottoms which pass through the slurry settler.

Dense phase catalyst overflows from the bottom portion of the reactor into a stripper, steam being introduced directly into the overflow and the stripper to remove hydrocarbons. The spent catalyst passes then into the regenerator and flows downwardly, counter-current to a stream of air from the air-heater. The gases from the regenerator pass to a Cottrell precipitator and are vented to the atmosphere.

The majority of the catalytic cracking plants of the Fluid Flow process which operated during the war had charging capacities of 10,000 to 20,000 barrels daily. During the war period Universal Oil Products Company designed a Fluid Flow catalytic cracker for small refineries. In one commercial operation 2,600 barrels of charge a day is processed. Fig. 2 shows the essential parts and flows in a plant of this type. The reactor is supported by the regenerator, which eliminates the separate structures required for its support in older and large scale designs. The overall height of a 3,300 barrel-per-day unit of this type is approximately 125 feet. The original overall height of large units was as much as 220 feet, but later changes in design have reduced this to about 155 feet. In the flow through the unit the oil feed is charged as a liquid at the base of the reactor riser. Hot catalyst from the regenerator enters the riser at the point of oil injection, furnishes process

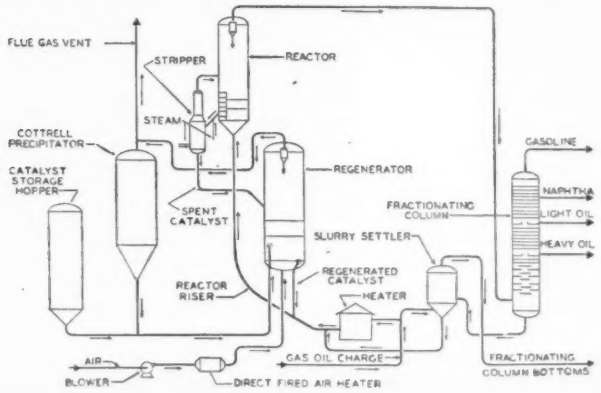

Fig. 1.—Fluid Catalytic Cracking Unit

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heat requirements and is transported upwardly into the reactor by the vaporized oil. Spent catalyst is withdrawn from the upper part of the dense phase to maintain the level in the reactor and passes downwardly through the stripper section into the regenerator. Steam as the stripping medium is injected at the bottom of both the internal and external strippers. Additional stripping of the catalyst occurs in the upper section of the regenerator where most of the flue gas from the combustion of carbonaceous material in the lower sections contacts the incoming catalyst, which passes downwardly concurrent to the air supply.

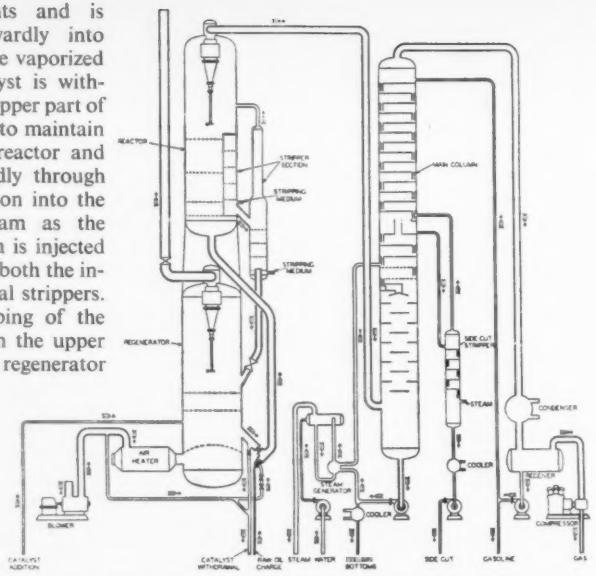


Fig. 2.—Fluid Catalytic Cracking Unit for small refineries

The regenerated catalyst flows from the lower section of the regenerator into the reactor riser at a controlled rate which maintains a constant reactor temperature. Combustion gases from the regenerator are vented to the atmosphere through an internal cyclone separator to recover catalyst. Similarly reaction products pass to the fractionator through a cyclone separator which returns recovered catalyst to the catalyst bed.

Distribution plates in the reactor improve the efficiency of contacting of oil and catalyst and give a higher liquid recovery and less gas formation. The addition of grid plates in the regenerator and stripper results in improved carbon burning rates and stripping efficiency with a corresponding decrease in operating costs.

Moving Bed Process

In the Moving Bed process extruded catalyst particles or macrospheres are employed, the catalyst mass moving slowly downward by gravity. Vaporized gas oil moves counterflow to or concurrently with the catalyst and the cracked vapours produced pass into a fractionating column, to be separated into gases, gasoline and furnace or diesel oil. The catalyst becomes coated with carbonaceous material as it flows to the bottom of the reactor where it is picked up by bucket-type carriers on an endless belt or chain and elevated to the top of a reactivating kiln. Some of these units are 225 feet high, but the latest types are of the order of 125 feet in height. In the reactivating kiln, the carbon is burned off by a stream of air moving counterflow to the descending mass of catalyst. The regenerated catalyst is then conveyed by another set of bucket elevators to a hopper from which it passes to the reaction chamber.

A schematic flow diagram of this type of process is shown in Fig. 3. The oil charge is heated and vaporized and

enters the bottom of the reactor to flow upwardly countercurrent to the descending catalyst. Any catalyst dust carried out of the reactor is separated and the vapours undergo fractionation into gas, gasoline, and gas oil. A spent catalyst elevator conveys the carbonized material to the top of the regenerator and a rising stream of air burns off carbon. Catalyst dust is again separated from the flue gas and the regenerated catalyst elevator returns the reactivated particles to a catalyst hopper above the reactor.

The yields of motor fuel and gases are of the same order as those obtained in the Fluid Flow process of operation, but the latter is a more flexible process.

Static Bed Catalyst Process

The third process is the Static Bed Catalyst process. The reactors comprise sets of parallel catalyst-filled vertical tubes, round which molten mixtures of sodium nitrate and sodium nitrite are circulated to impart heat to the hydrocarbon vapours and catalyst. The reaction can be controlled to a nicety to produce gas, gasoline, gas oil, diesel oil or recycle stock.

Fig. 4 shows a schematic flow in a Static Bed Catalytic Cracking Process. An intermediate boiling range gas oil fraction is first passed through heat exchangers to utilize heat from fractionator bottoms and cracked vapours, and then passed through a heater to complete its vaporization and raise it to a suitable cracking temperature. The vapours pass alternately through catalyst towers which are provided with inlets for air or other reactivating gas when the catalyst needs reactivation. The vapours are fractionated into gas, gasoline, and heavy gas oil, the gas is withdrawn for further processing or for use as fuel, and the gasoline is stabilized to a required vapour pressure.

Cycloversion Process

Another type of static bed process used during the war to a relatively small extent is known as the Cycloversion Process, which is essentially a process for producing gasolines having a high aromatic content. Granular bauxite is employed as a catalyst and the general flows in cycloversion plants are similar to those in other static catalyst bed processes. Yields of products are also of approximately the same order of magnitude.

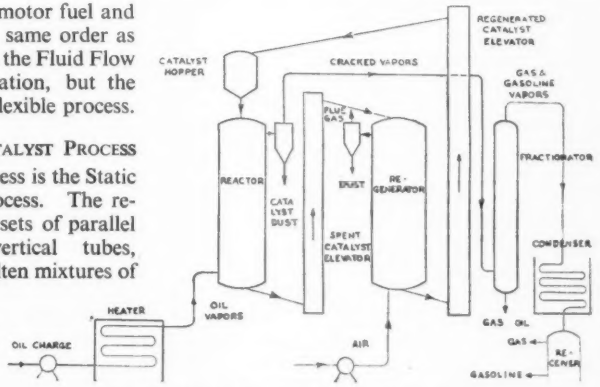


Fig. 3.—Moving Bed Catalytic Cracking Process

Suspensoid Process

During the war, Imperial Oil, Ltd. of Canada, developed the Suspensoid method of catalytic cracking and erected commercial units to process about 25,000 barrels per day of charge. In the operation of this process finely divided catalyst is slurried in the charging oil and the slurry is pumped through a tubular heating element wherein the temperature is raised above 900°F and pressures of about 400 lb. sq. in. are maintained. Yields of gasoline are about the same as in thermal cracking

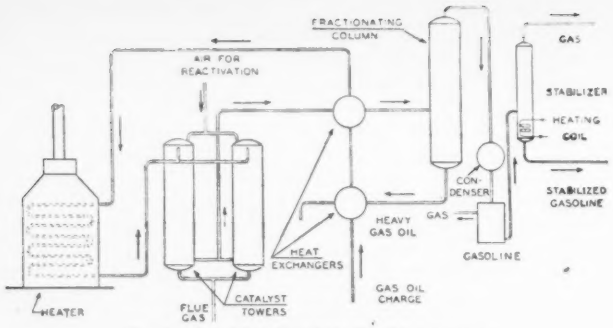


Fig. 4.—Fixed Bed Catalytic Cracking Process

but octane ratings are improved, values as high as 75 being obtained. In the early stages of development the process utilized spent clay from lubricating oil treatment as catalyst but later activated clays were used.

In May, 1945, the capacities of the various catalytic cracking processes in the United States were:

CAPACITY OF CATALYTIC CRACKING PLANTS

	Barrels per day charge
Fluid Flow	388,000
Moving Bed	325,000
Static Bed	318,000
Cycloversion	12,000
Total	1,043,000

These catalytic cracking processes are supplanting the thermal cracking of oils; i.e., the high temperature and pressure conversion of oils into motor fuel. The yields of motor fuel on a basis of charging stock and octane ratings are substantially higher than those from thermal cracking. Catalytic cracking processes when operated for the manufacture of motor fuel give yields of from 50 to 60 per cent by volume of charge. When they are operated to produce aviation blending stocks, yields of 40 to 50 per cent are obtained depending upon the character of the gas oil processed. Depending on charging stock, time, temperature, and catalyst activity, the octane rating of motor fuel from catalytic cracking ranges from 78 to 82, whereas thermal cracking yields motor fuel of from 66 to 74 octane number. When catalytic cracking processes are operated for the production of aviation blending stocks, octane ratings as high as ninety have been obtained with naphthenic gas oil charges. Furthermore, the gases from catalytic cracking are higher in both quantity and quality for the production of hydrocarbon synthetics and chemical derivatives than those from thermal cracking. Owing to the extreme flexibility of catalytic cracking units, particularly those of the Fluid Flow type, the process may be used to produce highly olefinic products, both gases and liquids. This point is of interest in connexion with the manufacture of chemical derivatives.

ALKYLATION

There was a wartime demand for maximum amounts of butylenes, propylene and amylenes—particularly butylenes—for the production of aviation gasoline by the alkylation process. Commercial plants using the sulphuric

acid alkylation process were in use before the war and a total of thirty plants were operating during the war period. In the original operation of this process, *iso*butane and butylenes, *normal* and *iso*, were mixed with sulphuric acid to form an emulsion, from which an alkylate *iso*octane mixture was obtained. In the wartime plants some use was made of amylenes in addition to butylenes. Sulphuric acid catalyst does not readily alkylate *iso*butane with propylene but rather tends to make *iso*propyl sulphate which is hydrolyzed to *iso*propylalcohol.

An important development in the alkylation field was the introduction of hydrogen fluoride as a catalyst. This compound effected the same reactions as sulphuric acid in the alkylation of *iso*butane with olefins and had definite commercial advantages, not the least of which was that the catalyst was a non-strategic material as compared with sulphuric acid in the war period. Hydrogen fluoride boils at 20°C (68°F) under ordinary pressures and it can, therefore, be used as a liquid at ordinary temperatures under slight superatmospheric pressure. It has no oxidizing effects on hydrocarbons so that it can be used without refrigeration in contrast to sulphuric acid which has oxidizing effects only obviated by using it at subatmospheric temperatures. The small amount of addition compounds that hydrogen fluoride forms with olefins in alkylation processes are readily decomposed by moderate heating so that substantially all the catalyst is recovered. Hydrogen fluoride is a very active compound, and we were strongly advised against putting up a commercial plant in which it would be used. The first unit built produced up to 7,000 barrels a day of alkylate. Twenty-seven units were installed and operated in refineries during the war to produce alkylate using the hydrogen fluoride process. *Iso*butane was alkylated with propylene, butylenes and amylenes in cracked gas mixtures obtained from thermal and catalytic cracking plants. Octane ratings of from 94 to 98 are obtained when *iso*butane is alkylated with butylenes, the highest rating being obtained when *iso*butylene is used. Alkylation of *iso*butane with propylene or amylenes produces alkylate having 90 or so octane rating. Alkylation processes initially used *iso*butane-butylene mixtures for the production of alkylate of high octane rating. As the demands for alkylate increased during the war, mixtures of propylene, butylenes and amylenes with *iso*butane were used to utilize all available olefinic material even though the average octane rating of the alkylate is somewhat lower.

A third alkylation process is also of importance, since it makes possible the combination of *iso*butane and ethylene. Sulphuric acid and hydrogen fluoride do not cause these compounds to react at any appreciable rate. The aluminium chloride-hydrogen chloride catalyzed reaction, however, produces the very hydrocarbons desired: 2·3-dimethylbutane, octane number 95, and 2·2-dimethylbutane, octane number 94, both of which have a high lead susceptibility. One commercial unit operated during the war to produce the two dimethylbutanes. The catalyzed alkylation reaction takes place at ordinary temperatures and moderate pressures, and this was responsible for the shutting down of a large non-catalytic thermal alkylation unit, operating at 4,500 lb and temperatures of 850° to 900°F to produce primarily 2·2-dimethylbutane. The catalytic process produces largely 2·3-dimethylbutane which has a higher lead susceptibility than the 2·2-compound.

The alkylates from sulphuric acid and hydrogen fluoride processes have been fractionated into individual components and structures have been determined by infra red, ultra violet and mass spectrometer methods of analysis. We look forward to a whole new chemical industry built up on these hydrocarbons

which can be produced in any desired quantities and at low cost. Aviation gasoline is now being considered as a source of chemical derivatives and many laboratories are studying its possibilities of conversion into new compounds.

JET FUELS

Developments in aviation are in the direction of jet and propeller-jet planes. Fuels for the gas turbines which are associated with these power units need to have closely limited characteristics to ensure good operation. These are:

(1) High energy content; B.Th.U. per unit weight;
(2) Clean burning, especially with large excess of air;
(3) High flash point;
(4) Low freezing point;
(5) Low corrosive properties;
(6) Low gum content.

These requirements are being met by certain high-grade kerosines at the present time. As demand increases it may eventually become as difficult to produce the necessary volume of jet fuels as it was to supply the 600,000 barrels a day of high-octane fuel needed at the end of the war by aeroplanes with reciprocating motors. The industry may then be called upon to provide synthetic jet fuels with as precise properties as are demanded for present 100-octane aviation gasoline.

CHEMICAL PRODUCTS

That we are in a chemical age so far as the oil industry is concerned is witnessed by the amount of catalyst that is being used in the industry. The daily consumption of catalysts in catalytic cracking processes in the U.S.A. is about 200 tons. This probably exceeds the total consumption of all catalysts used in the entire chemical industry outside of petroleum.

Ethylene from petroleum or natural gas is far cheaper than that manufactured by the dehydration of alcohol. The polymerization of ethylene at high pressures in the presence of traces of oxygen, produces a valuable plastic of high molecular weight. This process was originally worked out by Imperial Chemical Industries Ltd.

RUBBER

During the war, part of the normal butylenes in cracked gases were separated from the *iso*butylene, and dehydrogenated to butadiene for the production of synthetic rubber. Some of the butadiene is produced by the dehydrogenation of normal butane using aluminachromia catalyst at temperatures of 1,000° to 1,200° F. In one process benzene was hydrogenated to cyclohexane and this compound was thermally decomposed to produce butadiene.

Butadiene is polymerized with styrene. the latter being produced by reacting ethylene (from cracking or some other source) with benzene and dehydrogenating the ethyl benzene so formed. The proportions of styrene and butadiene used are 25 per cent and 75 per cent respectively. The type of rubber obtained is known as Buna "S" and represents the bulk of synthetic rubber produced.

Butyl rubber is produced by copolymerizing *iso*butylene and isoprene, the latter compound being the building stone of the hydrocarbons in natural rubber. The permeability to air of inner tubes made from butyl is one-twentieth that of those made from natural rubber; they also show more resistance to wear and tear. This is of extreme importance from the point of view of driving safety and tyre wear.

Another type of rubber is Thiokol made by treating ethylene with sodium polysulphide. This rubber is a yellow solid which has a decided and somewhat unpleasant odour. However, it is useful for outdoor work and many tons have been produced. Thiokol was pro-

duced before the war at the rate of ten tons a day and its production increased markedly during the war.

In the early days when we were dreadfully short of rubber, it was touch and go as to whether we could properly equip our aeroplanes, tanks, guns, and battleships, for want of rubber. We had the "know-how" of synthetic rubber manufacture based upon laboratory experiments years before the war came on. Fortunately, there were far-seeing men engaged in these experiments. Anyone travelling in Europe pre-war could not help but see that war was imminent. They were, therefore, prepared for the needs to be met by synthetic rubber. They knew that if and when a war came with Germany, submarines could sink ships bringing natural rubber cargoes into New York. All they had to do was to trap a few cargo vessels and a year's supply of rubber, i.e., 600,000 tons, would be at the bottom of the sea. The synthetic rubber plants in the United States produced some synthetic rubber at 50 or 60 cents a lb—or did, until they were shut down. Such high-priced operations were based on a high priced raw material, ethyl alcohol. Over 40 per cent or so of total butadiene in Buna "S" rubber came from ethyl alcohol by the fermentation of grain and other food supplies.

The estimated installation cost of the synthetic rubber units was about one billion dollars. Meanwhile the war was progressing and we were in need of rubber. Although the first batches manufactured were not too good. the product to-day is highly competitive with natural rubber. In the more efficient plants it is being profitably sold for 15 to 17 cents per lb as against a currently negotiated price of 23·5 cents per lb for natural rubber f.o.b. Far Eastern ports. The U.S. Reconstruction Finance Corporation has recently negotiated an agreement with the Netherlands for the purchase of rubber for 20·25 cents per lb at Far Eastern ports. There is no doubt that as we learn more about the production of the raw materials and the polymerization reaction, we will effect a reduction in the price to 10 cents a lb or so. If we were designing, building and operating new plants to-day, the price would probably fall below 10 cents. We have, therefore, an industry where economics and political factors as well as technology, are involved. Some groups wish to shut down all the synthetic rubber plants when the natural sources are in full production and can supply the needs of the world, but that is not going to happen despite some high ranking men in the U.S.A. who have recommended such action vigorously. They have shut down all the plants which have been using ethyl alcohol, as a source of butadiene for synthetic rubber due to high costs and their economic disadvantages. If we need ethyl alcohol, we can produce it far more cheaply from petroleum than from grain. Never again is the U.S.A. going to be caught short, as it was in the last war, with low stocks of rubber and no processes installed to make it when needed.

The laboratories of the United States have knowledge of at least 25,000 poor, fair and good types of rubber. Out of that number the rubber companies are sure of 500 different types of synthetic rubber good for specific uses. There is no need to rely on one substance to cover all rubber needs. There is no reason why the chemist operating with highly purified raw materials and with precise control of conditions of time, temperature, and catalyst, should not produce any type of product he requires. Our tyres may consist of four or five different rubbers, the various parts of the tyre and tube being constructed of rubber best suited for the specific service conditions to which they are subjected. One kind of rubber is best for the tread of the tyre which gets the bulk of abrasion and wear due to frictional resistance; the side walls need another kind; and

for the inner tube, still a different type is necessary. We are heading for tyres capable of more than 100,000 miles of travel service.

The peak of synthetic rubber production was reached in 1945, in the last of the war years. The total world production of natural rubber in 1941 was about 1,500,000 long tons. Of this quantity, the United States consumed a little more than half, or 775,000 tons. In the United States, the production of synthetic rubbers reached a maximum of 820,373 long tons in 1945. In 1945, the country's rubber manufacturers processed 1,040,045 tons of synthetic, natural, and reclaimed rubbers. The synthetic rubbers were mainly of the Buna "S" and the Butyl types.

EXPLOSIVES

In the United States, the oil industry played a prominent role in the production of high explosives and one of the basic materials was toluene. Fortunately, processes were available for the manufacture of toluene at the rate of 270,000,000 gallons a year, by the dehydrogenation of methyl*cyclo*hexane and cyclization of normal heptane or methylhexane. This was just nine times the quantity of toluene produced from all of our coal carbonization units in the States. Even though we did not have a commercial plant, we had our laboratory work ten years ago, but there was then no demand for toluene in any quantity, because the market demand was satisfied by toluene from coal tar sources. In 1918, when General Crozier was head of our high explosives production in World War I, he pleaded in the spring of that year that we should step up the production of toluene from 15,000,000 gallons to 18,000,000 gallons: one-eighteenth of that which was used yearly in the latest conflict. Every gallon of toluene, when nitrated, is good for 10 lb of T.N.T.—one of our primary high explosives.

We processed natural gas and refinery gases for hydrogen, which was used for the production of synthetic ammonia. Many plants were installed: the ammonia was converted into nitric acid and then into ammonium nitrate—used with T.N.T. in 20 ton block buster bombs which did a useful job in Europe and in the Far East.

Another type of high explosive was ammonium picrate produced from picric acid. Picric acid was produced by nitrating phenol. Part of the phenol from petroleum was used for picric acid manufacture and part for the production of plastics, such as bakelite, resins, etc. So again the oil industry evolved a supply based on a lot of pre-war chemical knowledge and experience.

We were also ready to utilize a glycerine process developed by the Shell Company—a beautiful job. Those of you who have ever experimented with hydrocarbons and chlorine at high temperature know of the explosions that may result and we had our quota. However, the reaction was controlled and the product converted by hydrolysis to produce glycerine, all of which demanded a high degree of operating skill.

FISCHER-TROPSCH PROCESS

The Fischer-Tropsch reaction between carbon monoxide and hydrogen can be controlled to produce a whole battery of products. High yields of ethyl alcohol can be produced—more competition for grain alcohol, which is already feeling the competition of alcohol from the sulphuric acid-ethylene reaction, the ethylene coming principally from petroleum. The Fischer-Tropsch reaction can also be controlled to yield motor fuel and diesel oil. Yields of up to 60 per cent wax have been reported. In the latter part of 1947, a commercial plant will be operated in Brownsville, Texas, the cost of which will be around $15,000,000. This plant has been designed to process 64,000,000 cubic

feet of natural gas per day, to produce 5,800 barrels per day of motor fuel, 1,200 barrels per day of synthetic diesel fuel and 150,000 lb per day of crude oxygenated products, principally alcohols. The natural gas used contains 92 per cent methane and is available at less than 5 cents per thousand cubic feet. When this plant goes into commercial operation, the process immediately becomes highly competitive with other methods for making formaldehyde and alcohols from methyl alcohol to dodecyl alcohol or higher.

The United States is now producing and consuming natural gas at the rate of about 4,000,000,000,000 cubic feet a year. The best estimates of our proved reserves are 140,000,000,000,000 cubic feet, so that on this basis we have about a thirty-four years' supply in sight, disregarding later extensions of fields and the discovery of new ones.

The Fischer-Tropsch process using the fluidized catalyst technique can also be adapted to the manufacture of gas, gasoline, gas oil and by-products from coal. The coal is treated with oxygen and steam to produce the hydrogen carbon monoxide gas mixtures. Estimates indicate that, for a plant which will make daily 40,000,000 cu. ft. of 1,000 B.Th.U. gas, 9,000 brl of gasoline, 1,800 brl of gas oil and miscellaneous oxygen-containing organic compounds, the initial investment is about 42,000,000 dollars. The gasoline production cost with coal at $2·50 a ton is then about 7·25c per gallon, if credit is taken for gas at 25c per cubic ft., and a reasonable amount for gas oil and chemicals. This cost includes no return on the additional investment needed over that necessary for producing gasoline by distilling crude oil.

There are those who are fearful of the rate we are using our oil supplies, and in the United States we still have the prophets of gloom who periodically say that in five years or so we shall be out of oil. We have more oil in sight now, in proven territory, than we have ever had in the history of the oil industry in the U.S.A., dating from 1859.

The output of chemicals, if the oil industry were to take over the whole U.S. chemical industry, would represent less than 5 per cent of the yearly oil production, which last year stood at 1,700,000,000 barrels of crude. We are using 20 per cent more oil to-day than pre-war.

Much work is going on in the States and a great deal has already been worked out in Russia where hydrocarbons like ethylene, propylene, and butylene derived from petroleum, are used as promotors of plant growth. Other experiments advanced some types of fruit trees and nut trees several months ahead of their normal growth Very important in the colder areas of the world! Ethylene is used for fruit ripening—e.g., for promoting the colour change in oranges from green to yellow. We have been able also to develop compounds which increase the size of potatoes; saturating or soaking seeds with hydrins produced from petroleum makes for quick germination.

The petroleum industry is also furnishing base hydrocarbon materials for the manufacture of chemical compounds used in agricultural pursuits. Apart from the chlorine used it is able to supply benzol and ethane, which are base materials with chlorine in the manufacture of the spectacular, newly discovered insecticide, D.D.T. It also stands ready to furnish materials for the manufacture of weed killers, such as the rapidly developing 2·4-D, whose chemical name is 2·4-dichloro phenoxy acetic acid.

In conclusion, much study is going on in the United States in connexion with the treatment of oil shale and coal by the fluidized method and by other methods. Our Government has turned over to the U.S. Bureau of Mines 30,000,000 dollars to be expended in five years' time for the purpose—

(1) of hydrogenating coal into oil;
(2) to work out a commercial process for economic recovery of oil from shale. A modest estimate is that the U.S. has 100,000,000,000 barrels of oil tied up in mountains of shale.

Part of the money is to be expended also in the utilization of forest products as fuels. The army has contributed—according to the U.S. Bureau of Mines' last report—a synthetic ammonia plant which will be converted into a coal hydrogenation set-up or hydrogenation plant for oils, etc.

RESEARCH

Many companies in the U.S.A. have embarked on vast research and development expansion programmes. The Standard Oil Co. of New Jersey, is putting up new research laboratories and increasing research personnel from 1,200 to 2,000. The Standard of Indiana has a big research programme and new buildings and equipment under construction; Sinclair Pure Oil Company, Union Oil Company and Standard of California are all projecting increases in their research programmes. Shell and Texas Company are all on a high tempo of new research with the objective of getting maximum values out of every barrel of crude oil. Many other companies could be mentioned, but these are some of the largest, and it can be certain that when they are all in full operation, the next ten years will witness even greater achievements than those of the past.

The automobile industry is also waking up to the needs of research on a great scale—to illustrate, Henry Ford states they are going to put up 50,000,000 dollars' worth of new buildings and equipment for research and engineering development, and General Motors has plans involving the expenditure of many millions for such work.

The race is on in the United States to increase scientific and technical personnel. To-day we do not have the number or calibre of trained men needed for the increased tempo of research development and engineering called for in the United States. During the war, we took our young men away from the universities and threw them into the army and navy leaving behind only women and physically unfit males. Attendance at universities and colleges fell almost to zero, but now there is a resurgence because our Government is helping returning or discharged soldiers to pay their way through colleges and universities. We are greatly undermanned on the teaching side; we do not have the school rooms, laboratories or equipment to handle the tremendous increase in applicants who want to go to school and start or finish their college or university work.

Until the universities of the United States resume their previous high output of graduates including those with doctoral degrees, we face a serious shortage of trained personnel for all types of research work both fundamental and applied. Various estimates by informed educators indicate that a pronounced shortage will persist over a period of from five to ten years. Vannevar Bush estimated in 1945 that there was a deficit of about 150,000 science and technology students who, but for the war, would have received Bachelor's degrees. He estimates that by 1955 there will be a deficit of about 17,000 advanced degree graduates in chemistry, engineering, geology, mathematics, physics, psychology and the biological sciences. All this in the face of the greatly expanded research programmes contemplated by practically all large industrial concerns.

A committee of the American Society for Engineering Education under the chairmanship of Dr. Karl T. Compton has estimated that in 1947 there will be 20,000 fewer chemists and chemical engineers in the United States than there

would have been without a war, and that by 1955 there will be an accumulated deficit of about 3,600 chemists holding Ph.D. degrees. All this will affect adversely the growth and development of the oil industry.

In summary we may safely anticipate that one of the major developments in the refining and utilization of petroleum will be production of ever-increasing amounts of chemical derivatives of the hydrocarbons originally present in petroleum fractions and those produced by alterations of the structures of original molecules. Petroleum furnishes a vast storehouse of base materials for the organic chemical industry and where now considerably less than 1 per cent of the petroleum produced in the United States is diverted into chemical channels, it is quite probable that in the next decade or so this will increase to over 5 per cent. Predictions are always hazardous but the present ones seem to be supported by a substantial array of facts.

The strength of the petroleum industry in the United States is shown by the increasing demand for gasoline and the corresponding increase in crude oil production to meet this demand and the demands for other petroleum products. After V-J Day most of the prognosticators were certain that there would be a slump in demand for petroleum products but such predictions have completely failed to materialize. The variations in crude and gasoline production and the number of motor vehicles registered in 1939, 1941 and 1945 are given in the following table:

Year	*Crude Production brl/day*	*Gasoline Production brl/day*	*Passenger Automobile Registration*	*Total Motor Vehicle Registration*
1939	3,465,000	1,670,000	26,147,798	30,644,568
1941	3,840,000	1,838,000	29,249,417	34,152,407
1945	4,780,000	2,135,000	25,301,345	30,158,240
Week ending May 10 1946	4,765,000	2,190,000	—	—

There was a 38 per cent increase in crude oil production from 1939 to 1945 and the rate of production is being maintained in 1946. Gasoline production increased 28 per cent from 1939 to 1945 and another 3 per cent increase is observed in the rate of production in 1946 compared to that of 1945. These increases are noted in the face of decreasing automobile registration due principally to obsolescence of passenger cars. The petroleum industry can therefore look ahead with assurance of ever widening demand for its products.

SYMPOSIUM ON OIL FIRES

The joint meeting between the Institute of Petroleum and the Institution of Fire Engineers on December 11th, 1946, at Manson House was gratifyingly well attended, beyond the seating accommodation in fact, and proved extremely interesting.

The attendance included representation from the French Ministry of the Interior, from the Administrative and Operative Staff of the N.F.S., from Admiralty and Army fire fighters as well as senior members of research organizations.

The papers were presented in a most interesting manner and the fact that discussion had to be brought to a close at 8.30 p.m. is tribute enough to the interest they aroused. The papers and subsequent discussion will appear in due course in the *Journal*, it being sufficient to say here that it became obvious that accurate knowledge of the science of oil fire-fighting is not nearly as widespread, even in oil circles, as one could wish.

PRODUCTION BEGINS AT KUWAIT

AN interesting new oilfield which has recently come into production is the Burgan field of Kuwait on the Arabian coast in the north-west corner of the Persian Gulf. Production began at 30,000 barrels a day in June 1946 and the large production potentialities of Kuwait are shown by the following assessment of Middle East oil producing areas published in America by *The Oil and Gas Journal* in June 1946.

Country	*No. of active fields*	*Production Brl. daily*	*Petroleum Reserves Million brl.*
Iran	6	385,000	6,000
Iraq	1	90,000	5,000
Qatar	1	—	500
Kuwait	1	30,000	5,000
Saudi Arabia	2	125,000	4,000
Bahrein Islands	1	20,000	250
	12	650,000	20,750

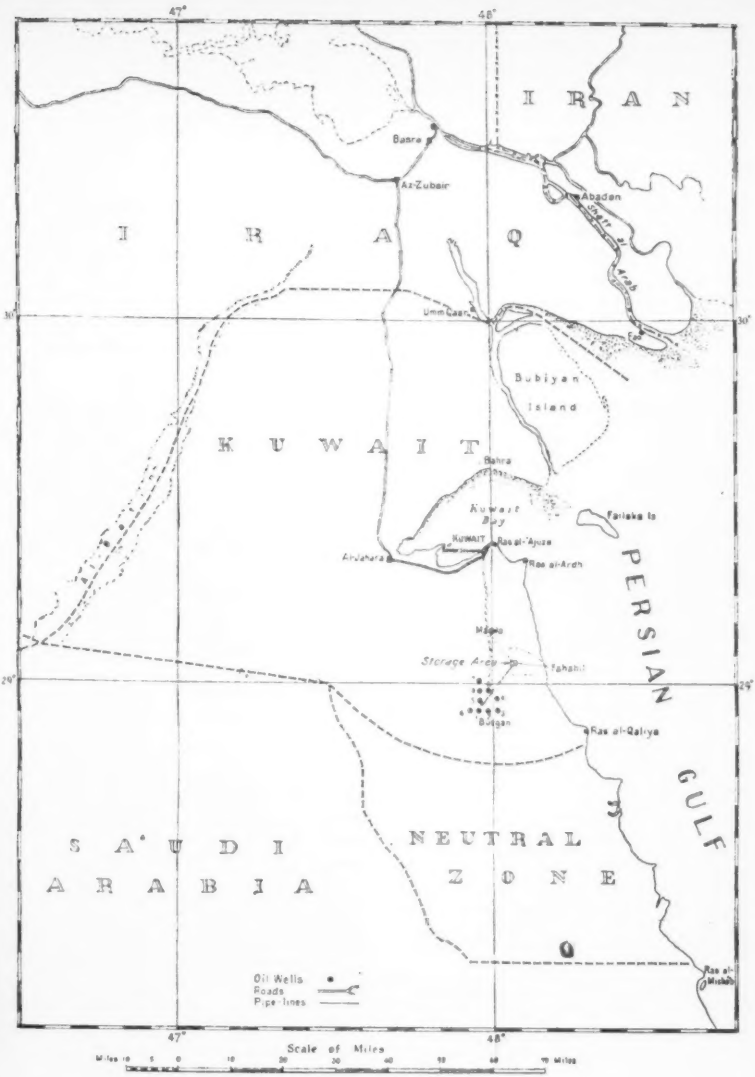
The Burgan oilfield is operated by the Kuwait Oil Co. Ltd., jointly owned in equal shares by Anglo-Iranian Oil Co. and Gulf Exploration Co., under a seventy-five years concession covering the whole territory of Kuwait granted by the Sheikh, H.H. Sir Ahmad-al-Jabir-as-Subah, K.C.S.I., K.C.I.E., in 1934. The discovery well was drilled in 1938 but war conditions delayed development of the field.

Kuwait is an independent Arab principality about 6,000 square miles in area, bordered by Iraq on the north and Saudi Arabia on the west and south (with an intervening neutral zone). It is mainly sandy desert with an annual rainfall of only 4½ inches, which has created a problem of water supply for the company. Drilling for artesian wells has had little success and a distilling plant has now been built to dispense with the import of drinking water from the Shatt-al-Arab.

Of the total population of 100,000, no fewer than 80,000 live in Kuwait Town, the only one in the principality, a boat-building and pearl-fishing centre of note. There is a small European community, also the American Mission with its excellent medical service. The British India Steam Navigation Company calls there regularly (the roadstead is about 1½ miles offshore, and the British Overseas Airways Corporation has an emergency flying boat anchorage.

Under the paternal rule of their progressive Sheikh, the Kuwaitis are a pleasant and orderly community, who provide a good local labour force for the oil company.

H.H. the Sheikh with Mr. Southwell (Managing Director), Mr. Scott (General Superintendent) and Mr. Patrick (Fields Superintendent), at the inaugural ceremony



The first indication of oil in the territory was revealed by seepages, but there was little other surface geological evidence. In 1936–37 the Kuwait Oil Company carried out geophysical surveys, and gravity, magnetic and seismic observations were made in the major areas of interest.

The first well was drilled at Bahrah on the north side of Kuwait Bay, but no oil was found, and it was abandoned in favour of prospecting in the southern part of the state. Here oil was struck at Burgan, about 30 miles south of Kuwait Town, in February 1938 at a depth of 3,672 feet.

Eight further wells were sunk, about three kilometres apart, varying from about 3,800 to 4,400 feet in depth, and all have proved flowing producers. The oilfield consists of several oil sands and five of the nine wells are dual-zone producers, the casing being pierced at those horizons from which it is desired to draw production. The crude is an intermediate wax-bearing paraffin of specific gravity 0·86 to 0·87.

H.H. the Sheikh of Kuwait opens a silver valve which sends the first export of oil from his country to the waiting tanker "British Fusilier"

War conditions put a temporary end to drilling in 1942, but operations were resumed in 1945 and the wells reconditioned. They flow to a single centrally-located gathering point where the final stages of gas separation are carried out.

The gas, which is free of H_2S, is at present used for distillation of sea water and will prove useful for domestic purposes as the permanent installations are completed.

The main oil storage is at Ahmadi, on a ridge 400 feet high overlooking the coast. Here there are four main storage tanks, each of 135,000 barrels capacity, fed by a 12-inch pipeline from the oilfield which is served by three diesel-driven pumps. From Ahmadi there is a 22-inch line with gravity feed to the coast near Fahaheel, the coastal shipping-point.

At Fahaheel, tankers cannot approach close inshore, and loading is therefore carried out by submarine lines, which run 4,700 feet out from high-water mark. There are two berths, one for ships arriving at the flow tide and one for the ebb, about half a mile apart. Each is served by a pair of submarine lines, the four being connected to the land line by a manifold at the beach-head.

The 22-inch production line to the manifold with four sea-loading lines leading to the tanker berths off-shore

The launching of the lines was carried out in June, 1946, at the rate of one per day over a four-day period. The time taken for the actual launch averaged only twenty-three minutes. They were towed out by the 11,000 tons S.S. *Iriquois*, aided by two tugs, and the whole operation proved remarkably successful and trouble-free.

The first shipment of Kuwait crude by the tanker *British Fusilier* was the occasion for an inaugural ceremony in which the whole population took part with zest. A silver valve controlling the flow of oil to the tanker was opened by His Highness the Sheikh, who was presented on behalf of the Directors, with a gold casket and scroll by Mr. C. A. P. Southwell, Managing Director of the Company.

The present throughput of 30,000 barrels a day is well within the capacity of the pipeline, which can take up to 50,000 barrels of crude oil.

Construction problems in Kuwait centre on two factors. The first is the blown sand carried by the wind which blows from the north for most of the year. Roads must therefore be kept constantly clear of drifts and sand-breaks are necessary wherever buildings are in an exposed position.

The second factor is the shortage of good building stone from local resources. Concrete is therefore used for the bulk of the permanent buildings.

Plans are being made to establish the permanent headquarters area at Ahmadi, where the high ground gives shelter from sand-drifts and there is a pleasant sea view.

FORTHCOMING MEETINGS

INSTITUTE MEETINGS

Fuels and Lubricants for Aero Gas Turbines. C. G. Williams. At 26, Portland Place, London, W.1. 5 p.m. Feb. 12.

Modern Developments in Geophysical Prospecting. Dr. A. Van Weelden. At 26, Portland Place, W.1. 5 p.m. March 12.

NORTHERN BRANCH

Petroleum Products and Problems in Electrical Engineering. L. Massey. At Engineers' Club, Albert Sq., Manchester. 6 p.m. Jan. 21.

Illustrated Dissertation on the Use of Petroleum Additives. A. E. Hope. At Engineers' Club, Albert Sq., Manchester. 6 p.m. Feb. 18.

SCOTTISH BRANCH

Oil Fires. E. Thornton. Pharmaceutical Society, Edinburgh. 7.30 p.m. Jan. 17.

Some Impressions of the German Coal Tar Industry. J. Idris Jones. At North British Station Hotel, Edinburgh. 7.30 p.m. Feb. 28.

SOUTH WALES BRANCH

Oil Fires. E. P. Lancashire, J. H. Burgoyne, L. L. Katan, N. O. Clark, E. Thornton and J. A. Lewis. At Britannic House, Llandarcy. 5.30 p.m. Jan. 14.

Lubrication of Steam Turbines, etc. S. J. M. Auld. At Britannic House, Llandarcy. 5.30 p.m. Feb. 6.

STANLOW BRANCH

Petroleum Products in Agriculture: The Role of Petroleum in Plant Protection. L. W. Leyland Cole. At Grosvenor Hotel, Ellesmere Port. 7.30 p.m. Jan. 22.

MEETINGS OF OTHER SOCIETIES

Recent Developments in Heavy-Oil Engine Lubrication. R. A. Collett. Diesel Engine Users' Assoc. At Caxton Hall, London. 2.30 p.m. Jan. 16.

Recent Developments in Testing Methods for Road and Building Materials. Society of Chemical Industry (Road and Building Materials Group). At Gas Industry House, 1 Grosvenor Place, London, S.W.1. 6 p.m. Jan. 16.

Low Temperature By-Product Development. W. A. Bristow. Institute of Fuel. At Institution of Mechanical Engineers, London. 6 p.m. Jan. 22.

The Operation and Development of the Fischer-Tropsch and Related Processes in Germany. C. C. Hall. Institute of Fuel (S. Wales Section). At Engineers' Institute, Cardiff. 5.30 p.m. Jan. 24.

Solid and Liquid Propellants. W. H. Wheeler. Institute of Fuel. At Institution of Mechanical Engineers, London. 6 p.m. Feb. 5.

Bond Lengths in Aromatic Hydrocarbons. J. M. Robertson. Chemical Society. At Sheffield University. 5.30 p.m. Feb. 13.

Resumed Discussion on Heavy-Oil Engine Working Costs, 1944–45. Diesel Engine Users Association. At Alliance Hall, London. 2.30 p.m. Feb. 13.

Production of Oil Fuel. J. S. Jackson. Institute of Marine Engineers (Junior Lecture). At East Ham Technical College, London. 7 p.m. Feb. 27.

Rubber, Natural and Synthetic. Society of Chemical Industry. At Institution of Civil Engineers, London. March 3.

KING FEISAL STUDIES OIL

H.M. King Feisal II of Iraq demonstrated his interest in the material progress of his country when he paid a recent visit to the Anglo-Iranian Oil Co. Research Station at Sunbury. Here he was shown maps and photographs of the Iraq oilfields and an exhibition of the crude oil produced therefrom and its various products. The young King spent an hour and a half in the various buildings studying the distilling, refining and testing processes, first in the laboratory stages and then in their practical application by means of large-scale development plant. He personally operated the controls in the Aero-Engine Testing Section and showed by his keen questions that he has a very real appreciation of the importance of the oil industry to Iraq.

Sir Frank Smith, Chief Scientific Adviser to the Anglo-Iranian Oil Company, demonstrates to King Feisal, by means of a laboratory apparatus, the distillation of crude oil

His Majesty was accompanied by H. E. Colonel Shakir al-Wadi, Iraq Minister in London, and Colonel Ubaid Abdullah, A.D.C., and took lunch with Sir Hubert Heath Eves, Deputy Chairman of the A.I.O.C., and senior officials of the company.

PERSONAL NOTES

A. L. Nickerson (Chairman of Vacuum Oil Co., Ltd.), until November 1 1946, has been elected a member of the Board of Socony-Vacuum Oil Co., Inc., New York.

H. W. Rocke, has been appointed Managing Director of Vacuum Oil Co., Ltd. Since joining the Company in 1933 he has successively held the positions of Chief Accountant, Secretary, and Director.

H. Holliday, who retired from the Managing Directorship of the Vacuum Oil Co., Ltd. at the end of 1946 has been with the Company for nearly half-a-century. He was made a Director in 1919 and Managing Director in 1933.

E. J. Dunstan, M.Sc., F.Inst.Pet., has been appointed General Manager of Manchester Oil Refinery, Ltd., and *J. C. Wood-Mallock*, F.Inst.Pet., M.I.Gas.E., has been appointed Refinery Manager. Other changes in the Company's staff are that *G. Tugendhat*, LL.D. (Vind.), M.Sc. (Econ.)(Lond.) joins *F. Kind*, Ph.D.(Vind.), M.Inst.Pet., as Joint Managing Directors, and that *H. L. Morris* has been appointed Secretary.

C. C. Crawford, Ph.D., has recently been appointed Assistant Manager of the Chemical Products Department of Phillips Petroleum Co., and in charge of the Special Products, Product Development, and Perco Divisions.

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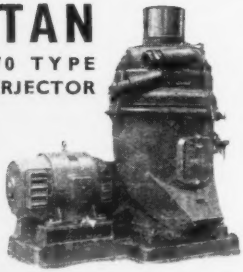

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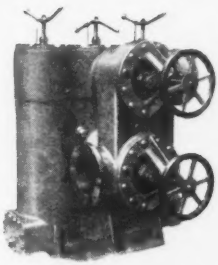

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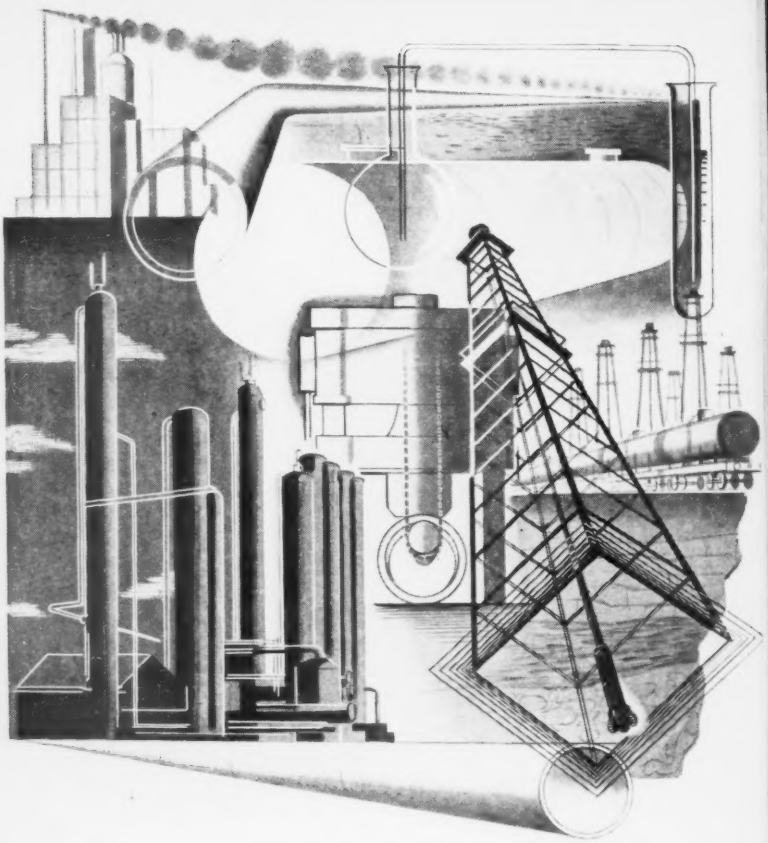

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INSTITUTE OF PETROLEUM

FUEL AND THE FUTURE

An account of the Institute's contributions to the Conference
organized by the

MINISTRY OF FUEL AND POWER

and held in London on
October 8, 9 and 10, 1946

SUPPLEMENT TO THE I.P. REVIEW.

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LIQUID FUEL INSTALLATIONS

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FUEL AND THE FUTURE

Ministry of Fuel and Power Conference

With the aim of initiating a drive for fuel economy, both as a short term and a long term measure, the Ministry of Fuel and Power held in London, on October 8, 9 and 10, 1946, a Conference under the above title. To assist in reducing the consumption of coal in Great Britain, it had been decided to import over the next few years a considerably increased quantity of fuel oil. The Institute of Petroleum was, accordingly, invited to organize a session on Oil Firing, with Professor F. H. Garner, O.B.E., as Chairman. The Council of the Institute delegated the task to the Co-ordinating Committee of the Liquid Fuel Installations Committee, who set up an *ad hoc* committee (see inside front cover) to make the detailed preparations.

The Conference as a whole was very successful, the contributions from the Institute and its members playing an effective part in ensuring this result. The following are extracts from a letter written by Dr. W. A. Macfarlane, Director of Fuel Efficiency, Ministry of Fuel and Power, to the Secretary :—

> " The Minister and the Fuel Efficiency Committee have asked me to write and express their great appreciation of the generous co-operation and support your Council rendered in the organization of the Conference on ' Fuel and the Future.'
>
> " We have received many congratulations on the high technical standard maintained in the different sections and on the smooth running of the proceedings. This was only made possible by the help of all those who took part in its proceedings and the assistance given by Institutes such as yours, in undertaking the responsibility of organizing and providing speakers for complete sessions, and of printing papers."

The Conference opened on the morning of October 8, with a general session at which the Minister of Fuel and Power, the Rt. Hon. Emanuel Shinwell, M.P., made an eloquent appeal for a nation-wide effort in fuel economy. Speaking of oil fuel, he said :

> " . . . . It must be some years before intensive mechanization . . . . can play any large part in increasing production [of coal].
>
> " Meanwhile, in order to assist in meeting the gap between production and consumption, we have improvised by arranging to bring substantial quantities of heavy fuel oil into this country. And I should like to pay tribute to those who have agreed to change over from coal to oil. I am sure that they will follow with special attention the addresses to be given at the session of the Conference on Oil Firing. It is regrettable that with our vast coal resources conversion from coal to oil, even on a limited scale, should be necessary ; but this is almost entirely attributable to the process of deterioration that has characterized the industry in recent years.
>
> " However, there are limits to the relief to be found from importing and using oil. These limits, to quote only two, are set by shipping space and the availability of oil-burning equipment. I take this opportunity of saying publicly that the limits of the present conversion programme have been reached. The new commitments already undertaken, added to our existing requirements, will absorb all the heavy oil for which equipment can be guaranteed within a reasonable period of

time. All commitments undertaken will, of course, be honoured ; but in considering further applications we should, I think, give priority to those processes where there is special advantage to be gained from oil firing, where the maximum quantity of coal can be replaced by the minimum of oil."

After the opening session, the Conference split up into eight sections running concurrently :

Section A — The Generation of Steam
Section B — Steam Utilization
Section C — Heat for Drying
Section D — High Temperature Processes (including the Oil Firing Session)
Section E — The Carbonization and Chemical Industries
Section F — Special Industrial Sessions
Section G — Modern Heating and the Architect
Section H — The Home and its Fuel Services

Although the Institute's formal session was accommodated in Section D, a number of members were asked to make contributions to other sections where appropriate.

Section A — The Generation of Steam

While this section was concerned in its first session with The Availability of Water-Tube Boilers, and in its second session with The Design and Operation of Small Boilers, part of the third session was devoted to Shunting Locomotives and included a discussion of oil fuel for shunting locomotives of the direct-fired steam, diesel and diesel-electric types. Mr. R. M. MACFARLANE submitted the following written contribution to the general discussion :—

" In delivering their papers, both Mr. Ketley and Mr. Diamond expressed the strong opinion that oil was not a suitable fuel for firing steam shunting locomotives, largely on account of boiler damage following from its use. That such damage has in the past been met with where oil fuel has been used is known. Comparable damage has in the past also been met with in practically every other heat using field of industry, and is almost invariably found to be due to non-observance of the requirements for properly supplying and utilizing the heat given by the fuel.

" Illustrative of this is the common experience of finding small shunting engines equipped with oil burning gear capable of steaming a main line ' Pacific ', the oil burner being stuck somewhere in the cab where the fireman cannot operate it without great difficulty. With the combination of such control gear and, consequently, unresponsive heat producing equipment, is it to be wondered at that the same effect has been met with as would follow from using on a small shunting engine the firegrate of the ' Pacific ', incapable of being fired properly and badly fired at a high rate ? It is, of course, physically impossible to fit the firegrate of the ' Pacific ' to the small firebox of the shunter, but not so a comparable oil burner.

" Where oil firing gear of capacity in keeping with the requirements of a locomotive is fitted and used in conjunction with control gear which *can* control it as required, effective and efficient service can be obtained from oil fuel on steam shunting locomotives, large and small, with no more firebox trouble than normal to steam locomotives as such—in fact, it may be less. Along with this go the advantages particular to oil fuel in comparison with coal in any application.

" Directions in which the fireless steam shunting locomotive can show advantage have been ably put forward by Mr. Hanna and Mr. Thirtle. Where the working

substance for this type of locomotive is supplied from boilers used for this purpose alone, the advantages and economy obtainable from oil fired boilers, particularly if automatic controls can be employed, should always be kept in mind.

" Mr. Stafford has shown that for the conditions at collieries the steam shunter can still offer attractions. Where these are tempered by inability to maintain locomotive power and availability owing to indifferent quality of available coal, use of fuel oil, properly applied, may offer advantage. The advantage would be associated as much with definite ability to cope with as much traffic as the engine could handle as with saving in the fuel it consumed which, as Mr. Stafford has mentioned, is but a small percentage of the tonnage hauled. Where technical and economic advantage can be obtained by doing so, there is nothing incongruous in using an oil fired locomotive at a colliery. Coal firing is used in oil refineries where technical and economic advantage accrues from its use. Maintenance of oil firing gear suited to a colliery steam shunting locomotive would be well within the capabilities of the average colliery mechanic.

" By giving attention to the points mentioned, an important concern abroad, operating a large quarry and associated industrial plant requiring close adherence to traffic schedules, was able to obtain from steam shunting locomotives, which they oil fired, trouble free service and performance which they describe as being the best they have ever experienced.

" Particulars of the locomotives concerned were :—

Type $\frac{0—4—0}{T}$

Steam : { Quality—saturated. W.P. 160 lb./sq. ins.

Firebox—copper.

Grate area { 3′ 3″ long × 2′ 10″ wide } = 8.89 sq. ft.

Firebox height : 3′ 3″.

H.S. Total : 449 sq. ft.

Cyls. : 2 off 11½″ dia. 16″ stroke.

Dia. coupled wheels : 2′ 6½″.

Operative and maintenance staff : Asiatic."

Weight in W.O. : 19.85 tons.

Wheelbase : 5′ 9″.

Rail gauge : 3′ 0″.

Loading gauge : { 11′ high, 8′ wide.

Frames : Deep plate.

Duties : Loads in region of 310 tons at about 5½ m.p.h. up 1 in 200 and at about 18 m.p.h. on level.

Section C — Heat for Drying

The first session of this very interesting section was devoted to Drying, Conditioning and Storing. It included accounts of the most efficient methods of drying food and waste products, penicillin and chemical products, china clay, hides and enamelled goods. While the emphasis was on solid fuel and its derivatives, Mr. K. H. SAMBROOK made an effective opening contribution to the general discussion as under :—

" The very interesting papers which have been submitted for discussion this afternoon have dealt with the improved methods of heat utilization in drying processes resulting in economies so necessary to-day in the consumption of coal and fuels derived from coal. In addition, it is intended to import into this country a greatly increased quantity of liquid fuel, and a few remarks on the use of liquid fuel for drying may, therefore, not be out of place.

" In considering where these increased imports of petroleum fuels can best be used, it is the opinion of the petroleum industry that, in general, this will lie in the field of high temperature processes, where the high temperature and emissivity of the oil flame result in a higher proportion of heat available for useful work at high temperatures. Nevertheless, there are many applications in the medium and low temperature fields where oil fuel has special advantages, and, of these, drying is an

important example. This is proved by the fact that in this country where, particularly with the imposition of a tax on imported liquid fuel, the cost of oil as compared with solid fuels based on the calorific value has been unfavourable to the use of oil, there are already many well established applications of oil fuel for drying. These are notably in the food-stuffs and agricultural industries. In drying processes the general advantages of oil fuel can be made good use of, viz., the ability to regulate exactly, under semi-automatic or fully automatic control if desired, the input of heat and the temperature of the drying medium. A still more important factor, however, as applied to convection driers used for the drying of delicate and sensitive materials, such as food-stuffs, is that by using a properly designed furnace, oil fuel can be burnt so completely that the products of combustion are innocuous and, after mixing with the necessary quantity of air to produce the temperature required, may be passed directly through the material to be dried without any deleterious effect on the product. As has already been mentioned in Mr. Hutt's paper, this means that, as compared with the use of a heat exchanger necessary when using solid fuels, the considerable proportion of heat in the fuel carried away by the exhaust products from the chimney is saved and utilized completely within the temperature limits of the process. This factor may easily result in a 25 per cent saving in fuel consumption (Mr. Hutt estimates a greater saving than this).

" In order to produce the necessary complete combustion certain points in design must be taken care of and some safeguards incorporated. Briefly, the important points of such a design are that the oil is burnt in a refractory combustion chamber where the high temperature necessary for quick and complete combustion can be maintained and that the oil is completely burnt in this combustion chamber without employing more than a normal amount of excess air before the diluting air is admitted and mixed with the products of combustion. In this way, the chilling of the flame before combustion is complete, which would occur if large quantities of diluting air were admitted at an earlier stage, is avoided.

" The safeguards provided are generally a diaphragm valve or similar device to cut off the fuel instantly should there be any failure or abnormal drop in the pressure of the supply of atomizing air to the burner. Secondly, a thermostatic or, preferably, a light sensitive device to shut off the oil immediately should the flame become extinguished for any reason.

" Granted complete combustion, the products will consist entirely of nitrogen, water vapour, excess air, carbon dioxide and traces of sulphur dioxide. The quantity of water vapour added to the drying air by the combustion of oil is so small, in relation to the increase in capacity for absorbing moisture produced by the heat released, that it has very little effect on the drying process. The sulphur dioxide is generally by no means harmful to food-stuff—the sulphuring of hops has already been referred to by Mr. Hutt. Providing also that the gases do not come into contact with surfaces at temperatures below the dew-point of the mixture, which will be very little above the dew-point of pure air under the same conditions, no troubles are likely to arise from corrosion.

" The use of these direct fired driers employing oil fuel for the drying of hops, grain, malt and grass is already well known and established in this country. It may not be generally known that oil fired direct mixing driers have been used for a number of years in the production of teas of the highest grade in Ceylon and elsewhere. The fact that this principle can be applied to the drying of such a delicate material as tea should reassure anyone who may still entertain doubts as to the risk of contamination of the material with the products of combustion from oil fuel. A further point which should be mentioned in this connection is that the products of combustion from oil fuel contain practically no arsenic. This was, for instance, a major factor in hop drying where the choice was either between a heat exchanger, with its higher capital cost and lower efficiency, or direct firing with an arsenic free fuel, which meant the choice either of oil or of the special grades of anthracite low in arsenic.

" The further advantage which oil offers, particularly in agricultural driers, is that it permits the application of regulated and controlled heat to portable machines where connection to gas or electricity supplies is inconvenient or impossible."

Mr. BOON (Chairman) :—" Before Mr. Sambrook stands down, Mr. Lehmann would like to ask him a question."

Mr. LEHMANN :—" I would just like to ask one question regarding the use of oil for direct firing. We have had a good deal of experience with oil installations, and have used it very successfully. Do your remarks apply to creosote pitch ?"

Mr. SAMBROOK :—" No, they do not. For the drying of the most delicate products, such as the case of tea drying mentioned, a distillate oil is preferred with which it is easier to secure the necessary perfectly clean combustion than with residual fuels such as creosote pitch."

A written contribution was also submitted to the third session, which dealt with Heat for Agriculture and Horticulture, by Mr. W. A. HUBBARD :

" Mr. C. B. Chartres has given us very valuable data on the subject of the artificial drying of grain, a development which has made steady progress and on which more attention than ever was focussed this year due, largely, to the wet harvest, and I should like to make the following comments on Mr. Chartres' paper.

" It is true that certain buyers of grain, particularly seed grain and malting barley, view with mixed feelings the use of the standard type of grain drier used in conjunction with the combine harvester. This can readily be understood by those who have seen such driers operated by unskilled labour on hand control and have noted the wide fluctuations of the air temperature.

" Many of us who have been concerned with the conversion of driers of this type to oil firing have insisted that the plants should be arranged for automatic control and, moreover, that each installation should include a recording thermometer, thus proving to the buyers that the maximum temperature ranges generally advocated have not been exceeded, but have in fact been constantly maintained.

" There is a division of opinion between those who advocate the small individual drier with each combine harvester and those who prefer the central or communal drier, and there are, of course, strong arguments in favour of both systems. The one difficulty that I have found in connection with the individual drier is the question of the capital cost of the original equipment and of any improvements that may afterwards be made to this equipment. For example, there are some hundreds of oil fired driers now in operation where the automatic controls are designed to regulate the oil supply only, on the high-low control principal, which means that at low flame the oil burners are operating with a considerable excess of air and, consequently, at a lower efficiency, whereas on the central driers, where the capital cost of the apparatus is not such a vital factor, oil firing plants have been installed which automatically regulate the oil and air supplies in proportion, thus maintaining a practically constant efficiency whether the plants are working under maximum or minimum load conditions.

" As Mr. Chartres has pointed out, most of the farmers' driers are fitted with furnaces of the pot type originally designed for hand firing with solid fuel, and, whilst many of these have been satisfactorily converted to oil firing, in many cases a higher efficiency would have resulted if the furnaces had been designed originally to burn liquid fuel—as many of them were in the case of the larger central driers.

" Whilst the capital cost mentioned in Mr. Chartres' paper for converting individual driers to oil firing is fairly accurate, a considerably higher capital cost must be faced to cover the conversion of central driers if the conversion is to be carried out on sound technical lines so that the oil fuel is consumed at maximum efficiency and labour charges reduced to a minimum.

" Mention has also been made of the economy that could result from (a) lagging, or heat insulation, and (b) re-circulation. Whilst these problems have not been seriously tackled in connection with ordinary grain drying plants, they have been for the drying and curing of malt, and the extra capital cost involved in efficient heat insulation and re-circulation of the gases has been fully justified by the resultant fuel economy. Whereas an average of 5 gallons of oil is required to dry and cure a quarter of malt on a standard type kiln, figures of less than 4 gallons per quarter have been obtained on kilns which incorporate re-circulation.

" As practically all the oil fired driers where the products of combustion pass through the charge are using Pool Gas or Diesel Oil, the calorific value figure of 18,000 B.Th.Us. per lb. given by Mr. Chartres is, of course, low, this particular grade of oil having a calorific value between 19,250 and 19,500 B.Th.Us. per lb. I also feel that the average farmer would be pleased to learn where he can obtain coal at 49/- per ton having a calorific value of 14,200 B.Th.Us. per lb. Some adjustment, therefore, is called for in the author's figures."

Section D — High Temperature Processes

This section was designed to include those high temperature processes carried on in the iron and steel industry, the non-ferrous metals industry and the glass industry. The opening session, under the chairmanship of Dr. C. H. Desch, F.R.S., President of the Iron & Steel Institute, was devoted to a review by representatives from the various industries of The Scope for Savings. It was followed by a session dealing with the longer term aspect involved in Furnace Design under the chairmanship of Mr. H. Southern, of the Society of Furnace Builders, who himself contributed the main paper. The third session was divided into two parts, the first under the chairmanship of Mr. G. N. Critchley, dealing with the Modern Gas Producer, and the second half, with Professor F. H. Garner, O.B.E., as Chairman, entitled ' Oil Firing.'

In opening the proceedings, PROFESSOR GARNER said that the discussion at the Oil Firing Session was designed to make a really practical contribution to modern problems. At the present time the imperative need was to use less coal and to promote the maximum economy in the use of all fuels. Although the title of the Conference was ' Fuel and the Future '—under which heading, incidentally, the use of atomic energy to replace fuel could be considered—the main attention must, for the present, be directed to the right use of different types of fuel, since it was this which constituted the true saving in so far as our fuel resources were concerned. The replacement of coal by fuel oil did not necessarily result in an economy in fuel, but the higher calorific value of fuel oil and ease of handling a liquid as compared with a solid must be taken into account.

An important question was that of availability for ordinary use, and here coal had a special importance in this country. An interesting example was afforded quite recently in which coke produced by the cracking of high sulphur crude petroleum had accumulated in very large quantities in California owing to the fact that no one could be found to use it. It was unsaleable although of quite high calorific value. This fuel had lately been transported for use in Germany and elsewhere for burning either by itself or mixed with lower sulphur content fuels.

The main subject at this session was the discussion of the most suitable uses for fuel oil, and it was that aspect which was dealt with in the paper on ' Liquid Fuel for High Temperature Processes,' by T. C. Bailey, F. J. Battershill and R. J. Bressey. This would be followed by four other contributors who would deal with special applications.

By way of introduction to the paper, MR. BRESSEY said that in view of the short time available he would endeavour to follow the advice given in Ecclesiasticus —" Let thy speech be short, comprehending much in few words." He first of all wished to explain that, in introducing this session on Oil Firing, it had not been the authors' object to give a dissertation on fuel economy in relation to liquid fuels. That subject was, of course, important and had been touched upon at the end of the paper. At the present time, however, when the increased use of *oil to save coal* rather than the saving of oil itself was the most pressing issue, it had been considered that they could more usefully devote themselves to consideration of the special features of oil as a fuel, and *where* and *how* the best use, from the national point of view, could be made of the additional supplies of fuel oil which were being made available.

As to the need for the particular approach adopted, it was the authors' view that the use of oil on land in this country tended to be conceived far too much in terms of boiler firing. They did not, of course, wish to deny that oil had attractions for this purpose, but they did submit that in the present critical situation, when fuels generally were in short supply, oil should, so far as possible, be used for those purposes where ' therms saved ' per ' therm of fuel oil used in substitution ' would be high. And by ' therms saved ' they meant calculated back to the raw coal. This was a particularly important point where secondary fuels were concerned.

This paper sought to demonstrate, MR. BRESSEY continued, that there were processes in which one therm of oil could be made to do the work of 1.4 or more therms of raw coal. By comparison, the general run of industrial boiler plants and power stations, where one therm of oil would replace little more than one therm of coal, was, from the national standpoint, a much less profitable field for the use of oil. Especially was this the case where the plant was right on top of the coal and the oil had to be hauled a considerable way from the importing installation. In this matter of boilers one was tempted to quote an almost prophetic couplet written by William Cowper 150 years or so ago—

" Our wasted oil unprofitably burns,
Like hidden lamps in old sepulcral urns."

" Seriously, though," the speaker continued, " this difference between 1 and 1.4 therms of coal saved by each 1 therm of oil used may well be an important factor in the balancing of the national fuel budget, as upon the thermal saving ratio achieved will depend whether 1½ million tons or 2 million tons of coal, or more, will be saved for each 1 million tons of oil put into use."

MR. BRESSEY then gave a resumé of the paper, the complete text of which follows. Concluding, he said that, although the bird's-eye review of the paper had been brief, his colleagues and he hoped that the paper would at least serve as the preface to a vigorous and useful discussion. Moreover, before he sat down, he would like to give to users an assurance of the maximum help and co-operation of the oil industry, the technical resources of which were available to all through the medium of the Petroleum Board.

LIQUID FUEL FOR HIGH TEMPERATURE PROCESSES

by

T. C. BAILEY, F. J. BATTERSHILL and R. J. BRESSEY

INTRODUCTION

1. The fact that the session on Oil Firing has been placed in Section D indicates that, in the opinion of the organizers of the Conference, high temperature processes constitute perhaps the most important field for the use of the increased quantities of fuel oil which are being made available in the United Kingdom. The authors of this paper share this view, and it is their purpose to demonstrate that it is the inevitable conclusion to be drawn from analysis of the facts of the case on sound technical lines.

2. Every fuel presents its own special technical features, which have to be viewed in relation to its cost and availability, and in the present critical situation it is essential that each of them should be employed for those purposes for which it is best suited and will give the best return, i.e., maximum output for minimum overall expenditure of heat. In other words, care must be taken to choose the RIGHT FUEL FOR THE JOB—indeed, this should be one of the very first considerations in any fuel economy campaign. Moreover, in the next few years the balancing of the national fuel budget may well turn on such apparently small factors as whether the extra 2 million tons a year of fuel oil to be imported can be made to save 3 million tons of coal or 4 million tons or more.

3. The special features of oil fuel are dealt with at some length in this paper and it will be seen that whereas a few of them may appeal to all industries, all of them will appeal only to a few. These few industries number amongst them, however, some of the basic trades of the country, such as those concerned with iron and steel and non-ferrous metals, and the particular advantages of oil for such industries will be given greater prominence than its more general attractions. The many successful applications of oil outside the high temperature field will not be referred to here.

4. Even when the present *oil to save coal* campaign has been brought to a successful conclusion, oil fuel will still be a comparatively minor factor in the British fuel market, supplying perhaps 3 or 4 per cent. of the total therms required, but it is, nevertheless, most important that it should be used efficiently and to the best possible advantage nationally. To this end the oil industry is co-operating wholeheartedly with the Ministry and with consumers, and it is hoped that this paper will make a useful contribution to progress in this particular direction as well as to the general purposes of the Conference.

CHARACTERISTICS OF LIQUID FUEL

5. There may still be a few who think that ' crude oil ' and ' heavy fuel oil ' are synonymous terms. This is quite wrong—crude oil is the liquid which comes direct from the oil wells and may be regarded as the raw material for all petroleum products. Petrol, paraffin oil, gas and diesel oils, and lubricating oils are produced by distillation of the crude oil, heavy fuel oil and bitumen being the residues left after the distillation process. The heavy fuel oils dealt with in this paper may all be classified as ' residual oils '—although their characteristics may vary considerably according to the crude from which they are produced and the extent to which the distillation process is carried.

6. Table I gives short approximate specifications for three typical heavy fuel oils—(a) and (b) being the Pool grades at present marketed by the Petroleum Board in the United Kingdom, and (c) being a typical heavier grade that may become available in the future.

TABLE I

Approximate Specifications of Fuel Oils

	(a) Pool Fuel Oil	(b) Pool Heavy Fuel Oil	(c) A 1500 secs. fuel oil
Specific Gravity at 60°F.	about 0.935	about 0.95	about 0.96
Flash Point (closed), °F. ...	150 min.	150 min.	150 min.
Viscosity Redwood I at 100° F., seconds ...	220 max.	950 max.	1500
Gross Calorific Value, B.Th.U/lb.	about 18,900	about 18,750	about 18,700

7. It is not proposed to comment in detail on all the characteristics of petroleum fuel oils, but it may be worth while to make observations on the properties included in Table I.

(i) *Specific Gravity* is no criterion of the general quality or other characteristics of a fuel oil. It may appear from an examination of specifications of various oils that the higher the gravity the more viscous the oil, but such reasoning can only be applied in a very broad sense. In point of fact, it is absolutely true only of oils derived from the same crude by straight distillation.

(ii) *Flash Point.* Fuel oils are high flash products, their actual flash points being well over the regulation minimum of 150°F. When stored and handled under proper conditions, therefore, fire hazards are no greater

with liquid fuels than with any others. It should be noted that flash point is a property of the oil in bulk and does not indicate the temperature at which the oil ignites when atomized ready for burning.

(iii) *Calorific Value*. As fuel oil is sold on a gallonage basis the calorific value per unit of volume is perhaps of more interest than that per unit of weight. Calorific values per gallon are, therefore, given in Table II.

TABLE II

Calorific Value of Fuel Oils on Volume Basis

Grade	Gross Calorific Value Therms per gallon at 60° F.
(a) Pool Fuel Oil	about 1.77
(b) Pool Heavy Fuel Oil	„ 1.78
(c) 1,500 secs. fuel oil	„ 1.80

Comparing the figures in Tables I and II, it will be noted that, although the lightest grade (a) has the highest calorific value per lb., it is the heaviest grade (c) which has the highest value per gallon. Other things being equal, therefore, it pays to use the heaviest grade obtainable.

(iv) *Viscosity* of a fuel oil is of great importance, being perhaps one of the best guides to its suitability for any purpose. In the U.K. viscosities are usually given in seconds as determined on the Redwood I viscometer ; other instruments are used on the European continent and in the U.S.A. (see Table III). Most specifications include only one viscosity, usually at 100° F.

TABLE III

Viscosity Conversions

Grade	Viscosity Redwood I at 100° F. seconds	Equivalent to :—		
		Kinematic viscosity stokes	Saybolt Universal seconds	Engler degrees
(a) Pool Fuel Oil ...	220	0.54	249	7.1
(b) Pool Heavy Fuel Oil	950	2.35	1,084	31.0
(c) 1,500 secs. fuel oil	1,500	3.71	1,712	49.0

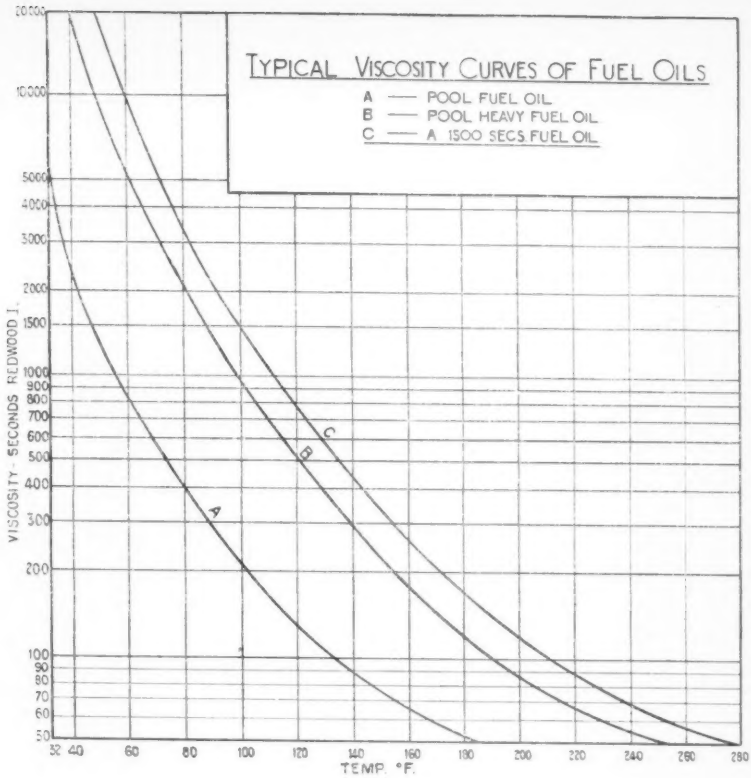

Figure I

Figure I shows the effect of temperature on the viscosity of fuel oils. By preheating, the more viscous grades can be reduced to the same viscosity as the thinner ones. Having determined the viscosity required for easy pumping and that required for correct atomization, the temperatures to which the oils must be heated can be read off the viscosity chart.

DELIVERY, STORAGE AND HANDLING OF LIQUID FUELS [1]

8. It is not intended to devote much time to a detailed description of all the various aspects of the delivery, storage and handling of fuel oils, but the authors feel that the paper would not be complete without reference to the main features of an oil installation suitable for the industrialist who is going to use fuel oil of the type described in Table I. To do justice to all the

technical points connected with the design and operation of such a plant would require a text book ; this section must, therefore, of necessity be somewhat cursory, but an endeavour has been made to include a few cardinal rules on design and operation.

9. It must be emphasized that a properly designed storage and handling plant is just as essential to the efficient use of oil as is a well designed furnace, and prospective users would be well advised to shun any suggestion of a makeshift ' hook-up ' of tanks and piping. The services of the Petroleum Board are available for the preparation of schemes for the storage and handling of fuel oil, and for general advice in this connection.

10. *Delivery of fuel oil* is made in road tank wagons, rail tank cars and tank barges. Coastal tankers are also available for delivery to users situated at suitable waterside points. Road wagons are fitted with power-driven pumps, but consumers taking delivery by other methods must instal their own pumps to discharge the oil. In the case of Pool Heavy Fuel Oil and more viscous oils, they must also provide steam for the heating coils of the tank cars and barges to warm up the oil and make it fluid enough for easy pumping.

11. *Storage tanks* should be installed above ground wherever possible and should be equipped with steam coils or electric immersion heaters to maintain the oil at a temperature at which it will be easy to handle. Approximate temperatures recommended for the storage of the three grades given in Table I are listed in Table IV.

TABLE IV

Oil Storage Temperatures

Grade	Recommended minimum temperature in storage tank(s)
(a) Pool Fuel Oil	45° F.
(b) Pool Heavy Fuel Oil ...	70° F.
(c) 1,500 secs. fuel oil	80° F.

It is recommended that, wherever possible, the heating medium in the tanks should be thermostatically controlled, the thermostats and the heating arrangements being situated below the oil draw-off from the tank so that they are never left uncovered by the oil. Cylindrical tanks are generally recommended and may be either vertical or horizontal.

12. *Transfer of the oil* to the burners should nearly always be done by means of a ring main through which the oil is pumped and returned to pump suction and/or storage tank. Gravity schemes, where oil flows by gravity from an overhead tank to the burner, are not advocated except for very small jobs where the tank and furnace are in close proximity. The ring main should be taken as close to the oil consuming points as practicable so that the branch lines to the burners can be kept as short as possible. The bore of the ring main will depend on the quantity of oil to be circulated, the length of the main and the viscosity of the oil at the circulation temperature. In some cases it will be necessary to bind a steam tracer line or pipe heating cables to the ring main (the two being wrapped and lagged together) in order to maintain the oil at the predetermined temperature.

13. *Heating the oil* before it reaches the burners will be necessary to reduce its viscosity so that it can be ' atomized ' and burnt properly. The temperature to which each grade must be heated will depend on a number of factors including the type of burner, the furnace in which it is being burnt, the process for which it is being used and the temperature of the combustion air. No hard and fast rules can be laid down ; the exact degree of preheat can only be determined by experience on each furnace. Table V, however, indicates the limits within which the right temperature will probably be found.

TABLE V

Oil Temperature at Burners

Grade	Oil temperature at burners °F.
(a) Pool Fuel Oil	110–140
(b) Pool Heavy Fuel Oil ...	170–200
(c) 1,500 secs. fuel oil	190–230

Note : In the case of pressure jet burners the lower limit of the temperature range will be about 20° F. higher and the upper limit about 50° F. higher.

14. The preheating of the oil for burning may be carried out (a) immediately after the pumps or (b) as close to the burners as practicable. If method (a) is adopted the oil will be circulated at the burning temperature (Table V) whereas in case (b) the oil will be circulated at storage temperature (Table IV). The choice will depend on a number of factors, and expert advice should be taken.

OIL BURNERS

15. All the oil burning appliances used for high temperature processes work on the principle of forming a fine spray or mist of oil particles, each of which can come into intimate contact with the combustion air. This is generally known as ' atomization.' There are numerous makes of British

burners on the market to-day which have been proved in practice to be very satisfactory and these are generally well known to industrialists. A note of warning should be sounded against the practice of using home-made makeshift burners ; these are often adopted in an endeavour to cut down the capital cost of the oil burning plant. Such a policy is usually ' penny wise and pound foolish ' and, in the authors' opinion, one that cannot be too strongly deprecated.

16. It is only necessary here to state the main categories into which the various types of burner fall. This classification can best be done according to the method adopted for atomization, viz. :—

(i) Pressure jet.

(ii) Blast atomizing type—

(a) Air jet, including low pressure air, medium pressure air and high pressure air.

(b) Steam jet.

(i) *Pressure jet.* Oil is atomized in this type of burner by being pumped at high pressure through a specially designed orifice, from which the oil spray issues usually in the form of a hollow cone. The pressure jet burner has not been used to any great extent on industrial furnaces, its main application being boiler firing.

(ii a) *Air jet.* Atomization is carried out in this type of burner by a stream of relatively high velocity air which strikes the stream of oil. The pressure of air employed ranges from $\frac{1}{2}$ p.s.i. (about 14″ w.g.) up to 150 p.s.i. and, for this reason, the air jet burners are usually divided into three classes—

Low pressure air	0.5 p.s.i.	to	1.5 p.s.i.
Medium „	„ 1.5 p.s.i.	to	10 p.s.i.
High „	„ 10 p.s.i.	to	150 p.s.i.

The lower the air pressure used the larger will be the volume to be passed through the burner for atomizing purposes. For example, a high pressure burner using air at 50 p.s.i. will only need about 2.5% of the total combustion air for atomizing purposes, while a low pressure air burner working at 1 p.s.i. (28″ w.g.) will need about 20% of the combustion air for atomization. Moreover, since air passing through a burner should not be preheated above 500° F., it follows that the use of low pressure air burners for high temperature processes, where the maximum use must be made of recuperators and regenerators to ensure economy and the high flame temperatures necessary, is rather restricted. High pressure air jet burners are generally recommended for this class of work, thus enabling the full degree of preheat to be applied to 97-98% of the combustion air.

(ii b) *Steam jet.* The principle of atomization by this burner is practically identical with that of the high pressure air jet burner. In general, steam atomization is not recommended for furnace work because it results in a slightly lower flame temperature. There are, however, special cases where a high pressure atomizing medium is required and steam is used because it happens to be readily available at low cost.

AIR SUPPLY

17. The means of providing the correct amount of air for the combustion of fuel oil is an important part of an oil burning plant. Each pound of oil will theoretically require about 180 cubic feet of air for complete combustion and, if efficient furnace performance is to be obtained, every effort should be made to achieve clean combustion conditions with as small an excess over this quantity as possible. Table VI gives the CO_2 content of the products of combustion of a typical heavy fuel oil with various percentages of excess air, and other useful data.

TABLE VI

Excess Air and CO_2 Figures

Excess Air % by volume	CO_2 in dry products of combustion % by volume	Actual air supplied per lb. of fuel cu. ft.	Vol. of wet products of combustion cu. ft.
0	16.0	181	192
10	14.5	199	210
20	13.2	217	228
30	12.1	236	246
40	11.2	254	264
50	10.4	272	283
60	9.8	290	301
70	9.2	308	319
80	8.6	326	337
90	8.2	344	355
100	7.8	362	373
150	6.2	453	464
200	5.1	544	554

Note : The gas volumes are at 60° F. and 30 inches Hg., air assumed to be dry.

It should be the aim of every oil user to work as closely as possible to the ideal of 16 per cent. CO_2 unless, of course, the furnace conditions demand otherwise.

18. The ability to burn oil with low excess air generally depends on three factors :—

(i) good atomization of the oil,

(ii) highly preheated air,

(iii) means of ensuring that the air is admitted correctly as regards place, direction and amount relative to the stages of combustion, so that intimate mixing of air and atomized oil takes place as required.

19. It may be useful to comment in more detail on these three factors :

(i) *Good atomization of the oil.* This depends on the burner used and its proper operation and maintenance.

(ii) *Highly preheated air.* Besides its other well known advantages, preheating the combustion air increases the rate and efficiency of combustion, thereby enabling the oil to be burnt satisfactorily with less excess air.

(iii) *Air control, etc.* All the air for combustion should be under control. Valves should be used for regulating a high or medium pressure air supply to burners, and slide or butterfly dampers for controlling a low pressure air supply, whether to burners or secondary air ports. Controls should be so designed that fine adjustments can be made, and should be marked, or fitted with indicators, so that predetermined settings can be readily obtained. In the great majority of high temperature furnaces 97-98% of the combustion air will be highly preheated; this will not be taken through the burners, but introduced as secondary air. It is important that the secondary air admission ports should be designed and located so that the air mixes intimately with the stream of oil particles. Well designed ports can make a considerable contribution to high furnace efficiency.

ADVANTAGES OF LIQUID FUEL

20. The general advantages of oil as a fuel may be summarized as follows :—

(i) Uniformity of quality.
(ii) Cleanliness.
(iii) Ease of storage.
(iv) Saving of labour.
(v) Controllability and flexibility.
(vi) Facility in handling.
(vii) Absence of ash.
(viii) High flame temperatures.
(ix) Luminous flames.
(x) High furnace efficiencies.
(xi) Greater outputs from furnaces.

These advantages are well known to many people but not by any means to all. It is thought, therefore, that no harm will be done by enlarging somewhat upon them, for it is the authors' contention that only by a comparison of fuels over every stage of their use can all the pros and cons be weighed up and the correct fuel from a technical angle be chosen for each individual job.

Uniformity of quality

21. There is very little variation from day to day, even from year to year, in the characteristics of fuel oil grades. This statement will probably come as a surprise to the industrialist who has become accustomed to almost daily variations in the moisture and ash contents of his solid fuel supplies—variations which have necessitated constant adjustment in operating conditions of gas producers and furnaces. The oil user, however,

having chosen the most suitable grade of oil and determined the correct operating conditions for his process, is virtually relieved of further worry as regards the source of heat. This is an important factor to-day when every heating process is tending to become a precision job and when thermal performance must be continually watched and analysed in the struggle for increased industrial efficiency. Uniformity of quality also means that the oil/air ratio for good combustion is always constant, so that automatic control is facilitated.

Cleanliness

22. The cleanliness of oil—which is handled throughout the works in an entirely closed system and produces neither dust nor ashes—is an important feature for those who desire clean shops and improved working conditions.

Ease of storage

23. Fuel oil has a high heating value per unit of volume ; it is a ' compact ' and concentrated fuel. To compare it with other fuels in this respect it is necessary to know the space occupied by each for an equal number of heat units, and this information is given in Table VII. The saving in space with liquid fuel is manifest.

TABLE VII

Storage Space Occupied by Different Fuels

Fuel	Approx. volume per million B.Th.U.
Fuel oil	0.9 cu. ft.
Anthracite	1.2 ,, ,,
Coal	1.5 ,, ,,
Coke	3.0 ,, ,,

In the majority of works a much freer choice of site is possible for oil storage than for coal storage, as the tanks need not be adjacent either to the furnaces or to the point where wagons are discharged.

Saving of labour

24. It has long been the endeavour of coal users to mechanize their coal handling and burning in order to eliminate unpleasant work, save labour and reduce the variations caused by the ' human element ' as much as possible. Oil users, however, have always enjoyed the full advantages of mechanical handling, since their fuel is handled by pumps from the moment it enters the works until it is consumed in the furnace. The oil handling plant is much smaller and simpler, and the labour required for its operation and maintenance is, by comparison, very small. Moreover, the work contrasts very favourably with the heavy and uncongenial labour involved in handling coal and ashes.

Controllability and flexibility

25. As a fluid fuel, oil is readily controllable—the heat input to the furnace being increased or decreased by the mere turn of a valve. Furthermore, it is capable of meeting variations in demand, however sudden, in a most flexible manner and is very well adapted to automatic control.

Facility of handling

26. This is really another aspect of the features mentioned in para. 24, but it is felt it calls for a separate heading in view of the way in which fuel handling often dominates an entire works. A higher degree of freedom in works lay-out is possible where oil is the sole fuel used.

Absence of ash

27. Fuel oil contains no more than a trace of ash, and this can, for most practical purposes, be neglected. There are no ashes or clinker to be removed and disposed of, and the fly-ash problem—which can be such a nuisance in furnace shops—does not exist.

High flame temperatures

28. Table VIII gives the approximate theoretical flame temperatures for various fuels burnt with no excess air and no preheat, allowing for dissociation.

TABLE VIII

Flame Temperatures

Fuel	Flame temperatures	
	° C.	° F.
Fuel oil [2]	2080	3780
Coal gas [3]	2045	3710
Producer gas [3]	1600	2910
Blast furnace gas [3]	1460	2660

29. In order to make a comparison of flame temperatures under working conditions, Figure II has been prepared for fuel oil and producer gas, each assumed to be burnt with 20 per cent. excess air and with varying degrees of preheat on the air and gas. It will be seen that while preheating does narrow the gap between the fuels, the margin in favour of oil remains substantial.

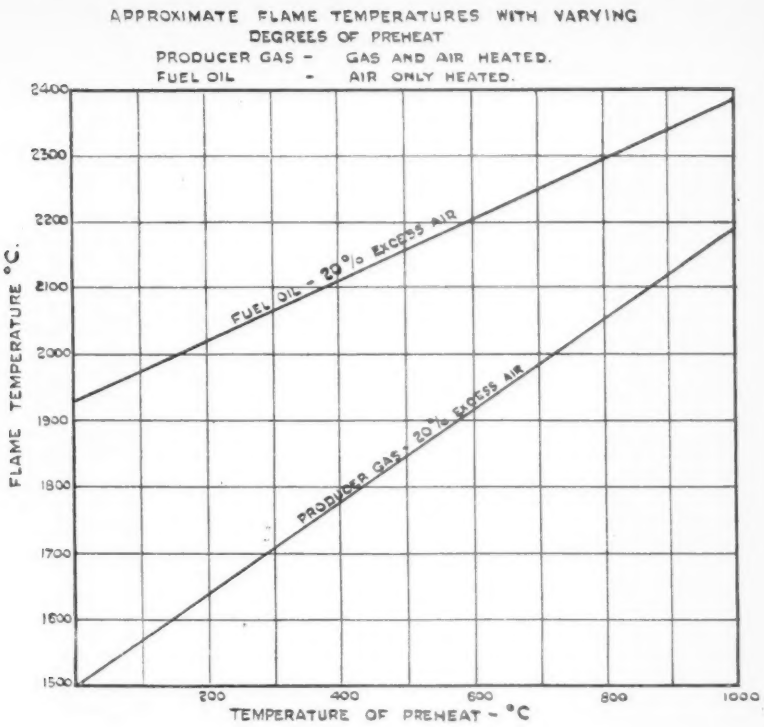

Figure II

Note: Although oil is taken as unheated in this graph, in practice it would, of course, be heated to the relatively low temperature necessary for efficient atomization (see para. 13). The additional heat supplied amounts only to about 80 B.Th. U. per lb. of oil, and would have an insignificant effect on flame temperature.

30. In order to demonstrate the great significance of high flame temperature in securing high rates of heat transfer, Table IX has been prepared. To make comparisons on some sort of practical basis, it has been assumed that the fuel oil is burnt with 20 per cent. excess air, preheated to 900° C., and that the producer gas is also burnt with 20 per cent. excess air, both gas and air being preheated to 900° C.

31. It is well known from the Stefan-Boltzmann law that radiation is proportional to the difference between the fourth power of the absolute temperature of the radiating body and the fourth power of the absolute temperature of the receiving body. For our purpose the equation may be considered in the following form :—

Heat radiated = $1730 \times E \times (T_1^4 - T_2^4) \times 10^{-12}$ B.Th.U. per sq. ft. per hour.

Where T_1 = Flame temperature in ° F. absolute.

T_2 = Working temperature in ° F. absolute

and E is a function of the emissivity of the flame (E_1) and that of the receiving body (E_2). E_2 need not be considered further here as, for given working conditions, its value can be assumed to be substantially the same irrespective of the fuel used.

TABLE IX

Comparison of Radiating Power of Fuel Oil and Producer Gas Flames

	Fuel Oil	Producer Gas
Flame temperature ° C.	2340	2120
,, ,, ° F. absolute (T_1) ...	4700	4310
	$(T_1^4 - T_2^4) \times 10^{-12}$	
Where T_2 = 1930° F. absolute (800° C.) ...	474	331
,, T_2 = 2290° F. ,, (1000° C.) ...	460	318
,, T_2 = 3010° F. ,, (1400° C.) ...	406	263
,, T_2 = 3370° F. ,, (1600° C.) ...	359	216

This table makes it abundantly clear that, for high temperature processes, a fuel oil flame has a greater ability to transfer heat by radiation than a producer gas flame. It will be seen, in fact, that its ability is over 60 per cent. greater where really high working temperatures, of the order of 1600° C., are concerned.

Luminous flames

32. The discussion regarding flame temperatures has so far disregarded the emissivity factor E_1, but as this varies with the fuel, and is of great practical importance, it must be taken into consideration when comparing fuels. Unfortunately, however, it cannot yet be evaluated by calculation as can the flame temperature. Practical furnace operators have long known that for many heating processes the transparent flames from certain gases are not conducive to quick and satisfactory heating, and have been seeking

a more ' solid ' and effective flame. It is now known that high temperature luminous flames provide just what the practical operator wants, but there still remains a considerable amount of research to be done to put the whole subject on a scientific basis.

33. It is well established that glowing particles of carbon cause the flame to become opaque and luminous, and that fuels which burn without such carbon particles tend to be transparent and non-luminous. This statement is supported by the fact that coke oven gas burnt without preheating produces a non-luminous flame, whereas when preheated to high temperatures the hydrocarbons it contains decompose and carbon particles are formed which become incandescent and give rise to some luminosity. Unfortunately, however, the calorific value of the gas is reduced at the same time, and this probably counter-balances the advantage gained by luminosity. Raw producer gas, on the other hand, owing to its tar content, produces a more luminous flame than other gases.

34. A. J. Fisher of the Bethlehem Steel Corporation[4] endeavours to assess the luminosity values of fuels on the basis of their luminosity-producing carbon contents, and some of his figures are reproduced in Table X. T. F. Pearson, in a recent paper on ' The Problem of Flame Radiation' [5], suggests the classification of fuels on the basis of the weight ratio between ' luminosity carbon ' and hydrogen, the former term covering free carbon, plus carbon obtainable from tar vapours and hydrocarbons, but not from any other source such as CO_2 or CO. Some of his figures are also given in Table X.

TABLE X

Flame Luminosity

Fuel	' Luminosity Carbon ' (Fisher)	' Luminosity Index ' (Pearson)
Fuel oil	44.5	6.08
Producer gas high tar		2.06
„ „ low tar	7.02	1.68
„ „ and coke oven gas 5 : 1 and 8 : 1		1.655
Coke oven gas	20.5	1.62
Blast furnace gas and coke oven gas 2 : 1		1.56
Blast furnace gas		0.00

35. Pearson's classification appears to agree better with practical observations than that given by Fisher. Both investigators, however, agree that, due to the presence of carbon particles, liquid fuels have a greater ability to produce luminous flames than gaseous fuels. These carbon particles, being solids, radiate heat according to the Stefan-Boltzmann fourth power law. Radiation from transparent gases does not follow this law, but is proportional to a lower power of the absolute temperature. In fact, the only gases which contribute a serious quota of radiation under furnace conditions are carbon dioxide and water vapour ; the contribution of other gases such as nitrogen, hydrogen and oxygen is negligible. Taking into account the luminosity of the flame, therefore, it would seem that the radiating ability of a fuel oil flame is even greater in comparison with that of a producer gas flame than is indicated in Table IX.

36. It is hoped that further research will throw more light on the subject of flame luminosity. Enough is known already, however, for it to be confidently asserted that the highly luminous flames from fuel oil are particularly advantageous where high rates of heat transfer by radiation are required and are superior in this respect to gas flames. Numerous examples in support of this statement could be quoted, such as the many instances where oil is injected into gas flames in order to improve them and the way in which oil is ousting gaseous fuels in the U.S.A. for steel melting in open-hearth furnaces.

37. To close this section, mention might be made of the methods adopted by Fisher for measuring and recording the total radiation from flames in an open-hearth furnace. Briefly, his method is to use a conventional total radiation pyrometer with a mica screen, the results being recorded on an arbitrary scale 0–100 and quoted as luminosity factors. In tabulating actual furnace outputs alongside recorded luminosity factors, he clearly demonstrates that, all other conditions being equal, furnace output depends very largely on flame radiation.

High furnace efficiencies

38. Having accepted the technical advantages of fuel oil set out in the preceding paragraphs, the industrialist will not be able to form his final opinion until he can make some estimate of how the consumption of fuel oil will compare with that of other fuels ; the question of furnace efficiences must, therefore, be dealt with. In the following comparison we have assumed that coal is burnt in probably its most common form for high temperature work, viz., producer gas. Table XI sets out the percentage of the gross calorific value of fuel oil and of producer gas which is potentially available for use within the furnace at various temperatures. These percentages represent the limiting efficiencies of the fuels with no heat losses from the furnace. Waste heat utilization by means of regenerators or recuperators would, of course, improve the results on both fuels, and would narrow the gap between them. Given the same conditions, however, for excess air and waste gas temperature, and the same percentage of waste heat returned by the regenerator or recuperator, the percentage of gross heat input potentially available in the furnace will always be greater in the case of fuel oil than in that of producer gas.

TABLE XI

Heat Potentially Available from Fuel Oil and Producer Gas

Temperature of gases leaving furnace	Heat potentially available	
	Fuel oil	Producer gas
800° C.	62.4%	55.3%
1000° C.	53.5%	44.4%
1200° C.	43.6%	33.1%
1400° C.	34.2%	21.7%

Note : These figures are calculated on the basis of complete combustion with the theoretical amount of air—no preheat.

39. Assuming that 45 per cent. of the heat in the gases leaving the furnace is returned as preheat, the percentage of available heat (where gases leave at 1,400° C.) then becomes 63.8 per cent. for fuel oil and 57.1 per cent. for producer gas. To complete the picture, the analysis should be taken one step further, i.e., back to the original raw fuel. The figure for oil then remains unaltered—whereas that for producer gas must be corrected by a factor for the producer efficiency. If this efficiency is taken at 80 per cent., the figure for producer gas then drops from 57.1 per cent to 45.7 per cent. To state this comparison in another way—for every therm given up in the furnace for a process requiring the gases to leave at 1,400° C., the theoretical heat consumption is 1.57 therms of oil or 2.19 therms of raw coal, or approximately one pound of oil against 2.00 pounds of raw coal. This conclusion is in line with the results obtained in various industries. In the case of glass melting in regenerative furnaces, W. A. Moorshead[6] also draws the same conclusion, i.e., that one pound of oil will do the work of two pounds of coal.

Greater outputs from furnaces

40. In the majority of high temperature processes, greater outputs can be obtained from furnaces fired with oil than from similar furnaces fired with coal or producer gas. This is not difficult to understand in view of the high rates of heat transfer obtained from the luminous high temperature flames of fuel oil. The consistent quality of oil also plays its part by giving the unvarying conditions which are conducive to continuous output at maximum rates.

HIGH TEMPERATURE PROCESSES FOR WHICH LIQUID FUEL IS USED

41. The value of the advantages of oil will necessarily vary from industry to industry and from process to process, but that they have been appreciated over a very wide field of application will be clear from Table XII. This

table does not purport to be exhaustive, but it is fairly representative ; examples of practically every type quoted are successfully operating in this country to-day. For convenience the processes have been grouped under a few broad industry headings.

TABLE XII

High Temperature Processes Using Oil

Iron and Steel	Open-hearth furnaces, soaking pits, reheating furnaces. Plate, bar and billet heating. Rotary melting furnaces. Welding furnaces for tube making, etc. Bolt and nut furnaces.
Non-Ferrous Furnaces	Smelting and refining, crucible and open flame furnaces for melting, billet heating.
Vitreous Enamel	Reverberatory and rotary frit melting furnaces, enamelling muffles.
Glass	Melting in tank and pot furnaces. Glory holes. Pot arches.
Clay	Beehive and tunnel kilns for refractories, bricks, tiles, pottery, etc. Sillimanite calcining, enamel melting.
Miscellaneous	Cement kilns, lime kilns ; gypsum calcining, alumina calcining.

The scale on which fuel oil is used in this country for these processes at present varies greatly. It can be safely asserted, however, that in many of them there is great scope for development in the use of oil, and this probably applies with particular force to the Iron and Steel, Glass and Clay industries. To conclude the paper, some brief notes are given on the application of oil to a few of the processes listed in Table XII.

Open-hearth Furnaces

43. The steel industry is displaying considerable interest in the oil firing of open-hearth furnaces as a result of the widespread use of oil for this purpose in the U.S.A. It is true to say that oil has very largely ousted producer gas in America, even where cheap and good coal is available. The principal advantages gained by the use of oil are :—

(i) Greater output from furnace (up to 30 per cent. increase).
(ii) Longer furnace life.
(iii) Simpler furnace construction.
(iv) No slag foaming.
(v) Lower labour costs.
(vi) No producer maintenance or burning out of gas mains.

Although the use of oil in open-hearth furnaces in this country is still in its experimental stage and the furnaces have been converted from gas firing and not designed for oil, the results to date are very encouraging. Table XIII indicates the fuel consumptions that are being obtained.

TABLE XIII

Oil Fired Open-hearth Furnaces

	1	2
Furnace capacity	150 tons	100 tons
Type of charge	66% hot metal	60% hot metal
No. of charges/week	9	12
Oil/ton ingots—single charges ...	31 gallons	28 gallons
Oil/ton ingots—overall, including maintaining over weekends ...	33 gallons	30 gallons
Gross B.Th.U./ton ingots—single charges	55 therms	49.7 therms
Gross B.Th.U./ton ingots—overall	58.5 therms	53.3 therms

It must be emphasized that these fuel consumptions are from furnaces that have really only been 'patched-up' for oil firing and not from furnaces specially designed for this fuel, such as there are in the U.S.A. Nevertheless, each ton of oil burnt is doing the work of about two tons of producer coal. It is hoped that as more open-hearth furnaces are converted, full details of the results on oil will be published.

44. The burners used for these furnaces, both here and in America, are generally of the steam jet type. Steam is usually cheap and plentiful in steel works, and its use helps to give the long and rather narrow flame that is necessary. The majority of the burners are made by the steel works themselves and are of a simple type. It is interesting to note that very fine atomization of the oil is not required for open-hearth furnaces. In fact, it is one application where really good atomization would be a disadvantage, as it would not give the particular type of long, luminous flame required. The right type and design of burner has been fairly well established. The best design of furnace for oil firing has now to be found and when this has been done it is confidently expected that the present oil : coal parity of 1 : 2 will be considerably improved.

Oil as an Auxiliary to Steel Works Gases

45. Reference has been made to the practice of injecting liquid fuel into gas flames in order to give them luminosity and so increase the rate of heat

transfer from flame to metal. This practice has been mainly confined to open-hearth steel furnaces, but it is suggested that it is one which might be extended to other furnaces in order to increase outputs and make better use of blast furnace gas, or release coke oven gas for other purposes. A few soaking pits and reheating furnaces have already been equipped for this method of dual firing, and results obtained to date indicate that increased rates of output are being obtained and that, even if only a small percentage of the total heat input is liquid fuel, the overall heat requirement is decreased.

46. A slab reheating furnace in Great Britain that has recently been equipped with dual firing is a continuous furnace, 80 ft. long × 20 ft. wide, from which outputs of 70 tons per hour have been obtained. The burners are arranged in three zones, the first zone (6 burners) being above the slabs, the second (6 burners) below the slabs and the final zone (8 burners) above the discharging doors. The first two zones, which, of course, supply the major portion of the heat input for heating the slabs, have been fitted with oil burners. The final zone, which is a soaking zone and, consequently, has a lighter load, has been left on mixed gas. The oil burners, which are of the steam jet type, have been inserted through the gas burners and arranged so that oil can be burnt alone or with gas, or gas burnt alone. The results have been very satisfactory, the furnace being extremely flexible and no longer dependent on the availability of the gas supply.

47. It is suggested that if this method was more widely adopted coke oven gas could be diverted to other uses for which a high calorific value, non-luminous gas is best suited. For example, if such gas was sold to public supply undertakings it would result in a useful saving of gas coal.

Rotary Melting Furnaces

48. Although a number of these furnaces have been in use for many years, there is still a field for their increased use in foundries producing special irons, where three features are essential—(a) ability to superheat to a high temperature, (b) absence of carbon pick-up, (c) close control of composition. They would also be very suitable for those firms whose production of steel castings is not regular and who require a flexible furnace which can be used for either iron or steel castings at short notice.

49. The furnace is one that is completely rotated during the melt. by which means a large percentage of the heat is transferred to the charge by conduction from the hot face of the lining as it passes beneath the metal. This enables the furnace to be worked at an extremely high rating without high melting losses. Steel tubular recuperators are employed in view of the intermittent operation of the furnace; all the air for combustion is preheated, air temperatures up to 450° C. being obtained. Table XIV quotes approximate performance data given by the maker of a design of furnace that has now become almost standard. The figures are for melting iron, and tapping at 1,450° C.

TABLE XIV

Approximate Data for Oil Fired Rotary Furnaces

	A	B	C
Capacity of furnace ...	1 ton	2 ton	5 ton
Time for preheating from cold	40 mins.	50 mins.	60 mins.
Melting time—first heat ...	110 mins.	140 mins.	180 mins.
„ „ —subsequent heats	90 mins.	110 mins.	150 mins.
Galls./ton iron, hot furnace	33 galls.	27 galls.	22.5 galls.
Gross B.Th.U./ton iron, hot furnace	58.5 therms	47.9 therms	40 therms
Overall space occupied by furnace, recuperator etc.	16′ × 15′ 3″	18′ × 16′ 3″	22′ 9″ × 23′

50. The efficiencies of these furnaces can be considered reasonably high in view of the limitations imposed on the air preheat temperature by the type of recuperator that has, of necessity, to be used. The actual heat absorbed by the metal is as follows :—

Furnace A ... 49 per cent. of the maximum theoretically possible.
„ B ... 61 „ „ „ „ „ „ „
„ C ... 72 „ „ „ „ „ „ „

Interesting experiments to improve combustion efficiencies on one of these furnaces by means of interlinked air/oil control are now being carried out.

51. The rotary furnace when used for melting *special* irons and steels demands a uniform quality fuel, preferably ash-free, which is flexible and can be brought into use quickly. Moreover, the high working temperatures and rates of output needed demand a luminous, high temperature flame. All these demands are best met by oil firing.

52. Similar types of oil fired rotary furnaces are used for melting and refining copper. An example of this use is a 10-ton capacity furnace which is melting a full charge in 65 to 85 mins., the full cycle of melting and refining being about 4 hours. The furnace is averaging about 33 charges in a week of 135 hours. The oil consumption works out at 8 per cent. by weight of the metal melted, i.e., 1 ton of oil is used for 12½ tons of copper. This overall figure for fuel consumption cannot very well be expressed as an efficiency in view of the fact that the process has two distinct phases : the melting period when a high rate of heat input is required, and a longer period when a lower rate of heat input is required to maintain temperature during refining. Here again the demand for controllability and flexibility is admirably met by oil fuel.

Rotary Calcining Furnaces

53. Liquid fuel is successfully used in long rotary furnaces of the cement kiln type where cleanliness of combustion is essential to avoid contamination of the material being heated. Such furnaces are often about 200 ft. long by

5 or 6 ft. diameter and are fired by a single oil burner along the axis of the drum or kiln, the products of combustion coming into direct contact with the material being treated. The combustion air is often preheated by the heat given up by the outgoing material. The actual oil consumption of a kiln of this type, with an output of just over 2½ tons per hour heated to 1,400° C., works out at 16 per cent. by weight of product heated. Results from two similar kilns, one oil fired and the other producer gas fired, show that one ton of oil does the work of just over two tons of producer coal.

FUEL ECONOMY [3 7]

54. The first step in true fuel economy is to choose the right fuel for the job or—put in another way, which is particularly relevant when fuels are in short supply—to see that each fuel available is used for those jobs for which it is best suited. In this connection, it is not sufficient just to consider efficiency of use in the furnace in isolation ; the analysis must be carried right back to the original raw fuel in order to get a true picture from the broader, national standpoint.

55. It is hoped that this paper has demonstrated that one of the most appropriate fields for the application of fuel oil is high temperature processes, where 1 ton of oil can very often do the work of 2 tons of coal. On the other hand, the general run of industrial boiler plants in this country, where 1 ton of oil will only do the work of about 1½ tons of coal, is not a profitable field for the use of oil, as on a thermal basis virtually no saving is obtained.

56. Where oil is used it is, of course, quite as important that fuel economy should be practised as where any other fuel is used, and various aspects of this question have been touched upon in this paper. Good design in the first instance is essential ; then, when the plant has been put into commission, fuel economy depends upon the correct operation and maintenance of the burner and air supply arrangements and upon the adoption of the many measures of heat conservation which are common to all fuels once their heat has been liberated in the furnace.

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OPEN-HEARTH STEEL FURNACES

Contributed by W. F. Cartwright, A.M.I.Mech.E. (Guest Keen Baldwins Iron and Steel Co., Ltd.)

The main advantages of a fuel oil shop over a mixed gas or producer gas shop lie in increased production of the furnaces while working, lower B.Th.U. consumption per ton and shorter repair times. The following are some points to which attention should be paid when converting an old shop or constructing a new one for burning fuel oil if the advantages of doing so are to be fully obtained.

A properly designed and served fuel oil furnace will have at least 10% faster production per working hour than the best producer gas furnace ; in addition, there is the possibility of continuous working as no burning out of flues is required. When compared with furnaces working on bad producer coal the difference is much greater. Comparisons between mixed gas and fuel oil are difficult to make due to the wide variation in the luminosity of various coke oven gases, but on high hot metal charges fuel oil has a marked advantage due to absence of foaming. However, no producer gas or mixed gas furnaces have ever approached the production figures of the best furnaces on fuel oil in America. Fuel consumption with good producer practice will seldom be lower than 7 million B.Th.U. per ton. Good mixed gas practice is about 5.5 million B.Th.U. per ton. Good fuel oil practice is 4.0—4.5 million B.Th.U. per ton. Actually, the fuel consumption on oil is about half that on normal South Wales producer practice.

With the tax on oil removed, the fuel costs per ton of ingots will be about equal on fuel oil and producer gas, but the increased production represents a definite cost saving.

To make the most efficient use of oil fuel on open-hearth furnaces, attention must be paid to the detail layout of the plant. A plant specially designed and laid out for oil fuel burning should always improve on the performance of one modified from producer gas or mixed gas practice.

Too often the charging facilities of an open-hearth shop, both for hot metal and scrap, can only just compete with furnace performance when working on producer gas. Therefore, a careful study must be made before converting to fuel oil to make sure that, with the increased melting rates possible with fuel oil, the charging time will not be a bottleneck. The same arguments apply to teeming facilities, which must be in excess of the output on oil to ensure that furnaces are never kept waiting.

As the viscosity of the oil supplied to the storage tanks is not necessarily constant, a continual check must be made and the thermostat on the pre-heater for each furnace re-set for every change. Good atomization will only be obtained if the viscosity at the burner remains reasonably constant for a given burner setting. For the same reason, pressure pulsations must be eliminated ; with adequate air vessels this is quite possible, even with reciprocating pumps, provided there are several units taking delivery of the oil.

In order to get the best possible combustion and to avoid roof damage, the elevation and vertical and horizontal angles of the burners must be adjustable, and the operators must see that the burners are adjusted to take care of any change in conditions.

The furnace itself should be specifically designed for fuel oil ; it is very wasteful to burn fuel oil in an out-of-date furnace with inefficient port ends. Obviously, adequate draught, combustion air and chequer volume must be available, but particular attention should be paid to the air uptakes and the spacing of the chequer work.

While the bugbear of burning out flues at week-ends necessary on all producer gas plants will be eliminated by the use of fuel oil, soot deposition in the chequers will still occur. Therefore, if the best results are to be obtained, soot blowing equipment must be provided and the chequerwork arranged to take care of it. This soot blowing equipment should be both at the side and underneath, the underneath blowers being used to blow back the soot blown down by the side blowers so that it can be removed from special man-holes. This side soot blowing involves leaving a large area of chequerwork uncased, and this expanse of brickwork should be sealed with some insulating compound sprayed on.

The furnace designed to burn fuel oil only has port ends of very simple construction, containing many less bricks than those on producer gas or mixed gas furnaces. The water cooling is also much simpler. There need only be two air uptakes, which should be of ample size, and these should be joined to form a bridge over the oil burner. The burner projecting between can then be kept very short and should be entirely free of maintenance.

As there are no gas chequers, slag pockets should consist of one chamber only at each end of the furnace ; access to the pocket should not be obstructed by casing or by a column. It is usually found when converting mixed gas or producer gas furnaces to oil that one of the main columns comes right opposite the centre of each slag pocket. This precludes the removal of the slag in one piece, which can be done in the case of a shop designed for oil with no obstructing columns.

The valve gear being for air only is of simple construction, and will give but little trouble. It is, in fact, this simplicity which gives throughout the furnace a saving in repair time.

In regard to the question of sulphur, fuel oil with a sulphur content of up to 2.5% has been used in South Wales to produce a steel of 0.04% sulphur, but if a steel of 0.03% sulphur or less is required it is more difficult and may necessitate stipulating an oil of somewhat lower sulphur content.

FERROUS METALS

Contributed by A. Stirling (Stewarts & Lloyds Ltd.)

The extensive experience of my Company of various grades of oil for firing batch type and continuous type reheating furnaces calls for only two special comments. We attach high importance to the regular and effective maintenance of the complete furnace system. Endorsing the authors' remarks about oil burners, it may be added that the burner block is no less important for successful and trouble-free production.

A general description of an underfired heat treatment furnace is appropriate to a Conference on Fuel and the Future. The furnace requirements were the accurate heat treatment, in the temperature range 600°C—900°C, of alloy steel bars, mainly of the 1% Ni. steel type. The stock varied from 2½"—7¾" in diameter, and from 2′ 6" to 3′ 9" in length. Eight of the maximum sized bars could be disposed on the 4′ 6" by 8′ 6" furnace hearth.

The combustion chamber had the above dimensions and was 2′ 0" high to the centre of the arch beneath the hearth. The chamber was built throughout of first grade firebrick and connected to the heating chamber through twelve vertical ports. The main ports were each 6" by 4½" (8) while at each corner there was a smaller port (4" by 3") to ensure a sufficient supply of combustion gases to maintain a positive pressure near the doors giving access to the heating chamber. The heating chamber was constructed entirely of insulating firebrick. The combustion gases exhausted through four 9" by 6" chimney ports to a simple waste heat recovery system.

Temperature control was maintained with a Kent Multelec Mark II Potentiometric two-point recorder linked to 10 S.W.G. chromel alumel thermocouples in 1¼" o.d. nichrome sheaths.

In addition to the satisfactory performance of creosote pitch as such, it was found possible to heat treat material with a mixture of this fuel and coke producer gas from a Government 5 therm producer (installed against a possible fuel oil shortage). It was the usual practice to raise the furnace to 610°C in three hours using 6 g.p.h. creosote pitch. With practically the same thermal input, this temperature was reached in 3½ hours when 45% of the thermal input was from the producer gas, and in 3¾ hours with 55% of the input as the gaseous fuel.

NON-FERROUS METALS

Contributed by J. Sykes (Enfield Copper Refining Co., Ltd.)

Having listened with interest to the paper on the use of liquid fuels in high temperature processes, I feel that it would be advantageous to review the use of fuel oils in the non-ferrous metals industry.

The main applications of fuel oil are as follows :—

1. Copper smelting and refining.
2. Reheating furnaces.
3. Annealing furnaces.
4. Light alloy smelting and refining.
5. Brass casting.
6. Zinc melting.

The use of liquid fuel in the firing of copper refining furnaces has many advantages over solid fuels. These can be summarized as follows :—

(a) Uniformity of quality—this, of course, is vital to the metallurgical operation.

(b) Much cleaner than coal.

(c) Simpler to control and makes for greater flexibility.

(d) Has no dust nuisance, generally gives a lower overall refractory cost and, due to there being no ash, only half the weight of slag is produced in the refining cycle, thus giving an appreciable saving in metallic loss.

(e) Shows an appreciable saving in labour—there being no raw coal to store, no costly pulverizing plant to maintain.

(f) It is much quicker to train furnacemen to fire with oil than with coal.

(g) Lastly, the most important point is the actual saving of fuel, and some actual figures obtained from a 175 ton capacity refining furnace are interesting. When using oil, the average consumption was 40 therms per ton of throughput, whilst with pulverized coal an average consumption of 50 therms per ton was required (no allowance being made for waste heat recovery). This gives a ratio of 1 ton of oil to 1.7 tons of coal—which from the national viewpoint is a considerable saving.

Reheating Furnaces

The wire bar, cake and billet reheating furnaces are mainly oil fired. Many of the advantages claimed for copper smelting and refining are also applicable to these furnaces, typical consumption figures being 5 to 6 gallons per ton throughput.

Aluminium Refining

In aluminium refining and smelting, oil fuel, due to its great flexibility and cleanliness, is the ideal fuel for this class of metallurgical operation.

Brass Casting

Oil fired crucible melting furnaces also offer many advantages over solid fuel. High calorific value and ease of operation enable a close degree of temperature control to be obtained. The greater cleanliness of working, due to the absence of ash and clinker, leads to substantial economies especially when melting the more expensive metals and alloys. Oil firing also shows much greater efficiency than coke fired furnaces, giving lower overall fuel cost and greater output with higher furnace efficiency.

Zinc Melting

Experiments have been carried out on a 50 ton zinc melting furnace which had an overall efficiency of 16% with coal, but showed a 25% efficiency with fuel oil.

Finally, after taking due consideration of the advantages to be gained in the use of oil as a fuel, one very important economic point arises. Comparing the reduction in the price of fuel oil against the continually increasing cost of coal, the use of fuel oil is to-day a much more attractive proposition to the industrialist.

GLASS MELTING

Written contribution from E. J. C. Bowmaker, M.B.E., B.Sc., A.R.C.Sc., F.R.I.C. (Davey and Moore Ltd.)

(read by G. Richardson)

The authors are to be congratulated on a most comprehensive survey of the subject, so much so that little is left for further comment. I will, however, attempt to formulate some remarks as regards the impact of liquid fuel on those sections of the glass industry about which I am qualified to speak.

It is obvious that whatever fuel is used for a particular process (and the selection of a fuel will depend on many factors) it should be used to the best advantage ; and the technique necessary, even with different grades of liquid fuel, will differ considerably. A set-up satisfactory to one liquid fuel, will, in all probability, be quite unsuitable to another liquid fuel. As an illustration, I was, during the War, concerned with the production of high silica glasses (Si 0_2 content approximately 81%), which were melted in furnaces of about 100 tons dead weight capacity. Recuperator heat recovery proved quite satisfactory using 200 seconds fuel oil, but it was found that creosote pitch was not successful because the large number of carbon specks produced by this fuel caused the glass to blister to a degree that rendered manufactured products quite useless. The carbon apparently reacts with the arsenates present in arsenic refined glasses to form CO_2 bubbles which will not clear themselves, particularly where the viscosity of the glass is high as in glasses of high Si 0_2 content. This necessitated a complete rebuilding of all the units to regenerative firing to ensure that carbon particles were not carried over the furnaces to the working ends of the units. It was found when the conversion was complete (an undertaking involving over two years' hard work) that the radiation from the melting ends was insufficient to keep the working ends hot enough to manipulate the refined glass (with these glasses, this temperature is of the order of 1420°C), and auxiliary heating had to be supplied to this part of the units. Two hundred seconds oil was used for the purpose, with varying success, with the normal burners available ; for some time, good results were obtained only when this portion of the units was gas fired. Eventually, an Urquhart atomizer was tried (giving almost perfect atomization of the oil) with complete success.

An incidental outcome of the conversion was a saving in fuel due to the use of high pressure burners, with consequent reduction in the percentage of unheated air, and to the greater heat recovery of the regenerative system.

One feature of the future use of oil in the glass industry, particularly where modern high speed melting techniques are concerned, is that of the greater control of the amount of fuel to the burner. With regenerative fired melting units, where sets of burners are in and out of use every 30 minutes or so, the temperature of the oil at the control valve varies considerably. Considerable fluctuation often is also experienced with the normal controls employed in the branch heaters leading from the ring main to the burner. The temperature viscosity charts given by the authors will show that quite considerable differences in viscosity can occur with these temperature fluctuations, causing varying quantities of oil to be delivered to the burners.

The latest opinion, both here and in America, indicates that even the best possible control of oil temperature gives an inadequate burner control for modern melting methods. The only apparent answer is the use of metering pumps, i.e., positive displacement pumps with a variable speed attachment, which deliver to each burner an exact and constant supply of oil under all conditions of oil temperature fluctuation likely to be met. I feel that the use of metering pumps will become more and more widely used in the industry as more exact temperature gradient control in the melting units becomes necessary to obtain the best rates of melting. This fact became self-evident when it was shewn that, by exact control of temperature gradient, greatly increased melting rates could be obtained for the same heat input. It may well be that variation in oil temperature at the burner is one reason why I have never been able to operate regenerative furnaces at so consistently low a figure for excess air as has been possible with regenerative furnaces fired by producer gas. Gas fired regenerative units have been run consistently at 5% excess air, but oil fired regenerative units average much more nearly 10-12% excess air. This state of affairs does not apply to recuperative units using oil firing where the excess air can be easily controlled to quite low figures.

Many though the advantages are of oil firing in the glass industry—which the authors have brought out so admirably—there are disadvantages. The chief of these is the intensely local action of the flame causing a great increase in furnace wear both above and below the glass level. The life of furnaces is shortened and the repair bill increased by its use. Nor can it be claimed successfully that the output rate is better by the use of oil than, say, producer gas, notwithstanding the latter's lower flame temperature. Therefore, this aspect of oil firing must be placed on the debit side.

It appears that the high radiation factor of oil flames can only be obtained by comparatively short hard flames, and this definitely limits the heat input to the melting unit. The experience of many glass technicians must be in line with my own, in that often, although the limiting factor as regards heat input is the danger to small but vital parts of the refractories by the localized radiation of the oil flames, to spread the advantage of the high flame temperatures obtained by oil flames would only seem possible by a cumbersome multiplicity of burners. This may account for the fact that the highest melting rates, expressed in tons of glass melted per sq. ft. of melting area, have been obtained, so far as I can ascertain, by gas fired units where, although the luminosity of the flame may be less, it is much more dispersed in its effect. In this connection, it should be stressed that these remarks only apply to glass manufacture. The conditions attending steel manufacture, for example, are quite different, and experience there may, therefore, run to contrary conclusions.

The authors have made some play on the fact that a certain weight of oil can give results achieved only by a greater weight of coal. Such statements in themselves have little meaning and are not justified even in bolstering up such expedients as are fashionable now. Unfortunately also, the best fuel for the job can often not be used because the final determining factor is not, as the authors state, that which gives the maximum output for the minimum overall expenditure of heat, but that which gives the maximum output for the minimum expenditure of money—and the terms

are by no means synonymous. During the 1926 coal strike, many glass-making concerns went over to oil firing in spite of the fact that the cost was higher—the difference in cost was endured as an insurance. But even when cheap creosote was available (i.e., it bore no tax) up to 1939, the last year that the various fuels found their own price levels, coal firing by way of producer gas with its attendant additional costs was, in the main, the cheapest method of firing (I am neglecting certain restricted areas where coke oven gas was supplied at a by-product rate) in the glass industry. In support of this contention, I can instance one very large glass factory which undertook a conversion from fuel oil to producer gas as an economic proposition. The ideal would appear to be a dual system, designed to change from one to another as the market determined. The proportion of the total cost of glass manufacture represented by actual fuel charges is such that a dual system may quite well pay for itself by taking full advantage of even small price differentials, besides adding to the insurance against failure of supply of one fuel or another.

Replying, Mr. T. C. BAILEY, as one of the authors of the original paper, said how glad they had been to have Mr. Cartwright's contribution on the efficient use of oil firing in open-hearth steel furnaces. Mr. Cartwright had described one of the few new developments in oil firing established here in recent years, and it was an application where all the advantages of oil could be used to the fullest extent. He and his co-authors were also very glad to have such an authoritative statement that the repairs to the furnaces could be carried out in a much shorter time than on a gas fired furnace. This should be reassuring to those people who were converting to oil fuel.

One point with which he was in entire agreement, and which he rather wanted to stress, was that the furnace should be specifically designed for oil in order to get the best results. This recommendation applied to all applications of oil firing, and, in this connection, he rather disagreed with Mr. Bowmaker's suggestion that furnaces should be laid out so as to use either oil or gas, whichever happened to be cheaper at the time.

Mr. Bowmaker had frankly told them the disadvantages of oil. He wondered whether his experience had been due to his method of the application of oil, because many glassworks were securing higher rates of output with oil than was normal with gas firing, and the furnace life had not suffered. Incidentally, he wanted to urge a plea that furnace life should be quoted in terms of output rather than in terms of time.

Again, he wanted to come back to the question of designing furnaces for oil and not trying to convert a gas fired furnace for that purpose. The glass designers knew that port design and the position of the burner were points that needed very careful consideration, and he wondered whether the experience of the steel industry in this connection might not be helpful to designers of glass furnaces.

With regard to the contributions by Mr. Stirling and Mr. Sykes, it was very pleasant of them to emphasize all the advantages which had been mentioned in the paper as having a considerable value in actual practice. Both these contributors had had much experience in using liquid fuels over a wide range of application, and their statements, therefore, had been of great interest.

The CHAIRMAN then invited general discussion.

A. W. J. DYMOND (Great Western Railway Co., Ltd.) said: "As a contribution to the discussion on the subject of oil firing, it would, I think, be not inappropriate to refer to the steps being taken by the Railways of this country, at the request of the Ministry of Fuel and Power, to convert a proportion of their locomotives to oil burning, thus releasing coal for other purposes. The target at which the conversion aims is the release of approximately one million tons of coal per annum. This entails the conversion of 1,229 locomotives and the installation of 60 oil storage depots spread throughout the country.

" Prior to this large scale conversion, the Great Western Railway had converted ten of their large 2-8-0 freight engines to oil burning and had installed two storage installations in South Wales, and were proceeding to expand this to a number of their large 4-6-0 four-cylinder passenger engines with an increase in storage depots by another seven. Their experience with oil burning on their own locomotives was so satisfactory that the large scale conversion now being undertaken by all Companies is based on Great Western Railway practice, which was evolved in conjunction with the North British Loco. Co., Ltd. and the Petroleum Board. In a large number of the details the Great Western design of the components is being adopted as standard for all Companies' engines.

" The consumption of oil throughout the country when the conversion is completed is expected to be about 2,500 tons per day, and, in order to ensure adequate supplies always being available, storage capacity of approximately 43,000 tons is being installed. This represents a fourteen-day supply in tank capacity, which has been recommended for safe stand-by by the Petroleum Board.

" This large scale conversion of locomotives to oil burning is probably one of the most comprehensive operational changes ever undertaken by the Railways of the country as a whole, and the fact that it is intended to carry it to completion within a few months is entailing the use to the fullest extent of all the Companies' resources, particularly on the technical and design side, both for the locomotive equipment and the storage installations.

" The Ministry of Supply is undertaking to supply to the Railways or their Contractors the whole of the equipment necessary both for the engines and the storage plants, and a start has already been made on the production of the vast quantities involved. The magnitude of the undertaking can be gauged from the fact that two rail tank cars of 3,000 gallon capacity each will be kept in constant service to supply each locomotive with oil.

" The equipment on the locomotive consists of a Weir type burner situated under the tubeplate in the firebox of the engine, the oil being atomized by means of a steam jet. A new floor to the firebox is necessary, and the bottom portion of the walls, as well as the floor of the box, are lined with special high alumina content refractory material. Each tender is to be fitted with a steam heated oil fuel tank, and provision is made for connecting the locomotive to an auxiliary supply of steam when lighting up from cold.

" In the locomotive shed yard, the problem of siting the large storage tanks and finding room for the necessary sidings for the reception of the rail tank cars simultaneously with the berthing of locomotives for refuelling has necessitated the exercise of considerable ingenuity to avoid undue dislocation of the usual method of working in the depots.

" When an engine is converted to oil burning, not only is a saving of coal effected, but labour now necessary on each coal burning locomotive for the cleaning of fires, de-ashing of ashpans, smokeboxes, etc., is eliminated, and the turn-round time of the locomotive at the depot can, if train services permit, be reduced very considerably. On the road, the engine is capable of maintaining the highest evaporation rates for lengthy periods owing to the removal of the restrictions experienced with the coal burning locomotive by its dependence upon the physical effort of the fireman and the fact that there is no deterioration of the fire due to choking of the firebed by ash and clinker. The fireman's duty with an oil burning locomotive entails, however, close and intelligent co-operation with the driver's working of the engine.

" Based upon Great Western Railway experience, it can be said that the oil burning locomotive, both on the road and in the shed, exhibits considerable advantages over the coal burning engine. From the point of view of cost, of course, the balance is still against oil, but the present stringent coal position and the vital necessity of maintaining public transport despite all difficulties, renders the conversion to oil essential. It is, nevertheless, a matter of grave concern that the Railways of this country must turn to the use of an imported fuel for their operation, even to the point of hauling trains of coal by locos fired with oil."

Mr. WHEELER said that he would suggest if any difficulty was found in getting an oil burner the paint spray nozzle should be used.

PROFESSOR LESLIE AITCHISON said that during the day, in other sessions of the Conference, he had already made one or two comments on the use of oil fuel in the non-ferrous industries, by which he particularly meant the copper and brass trades. To these industries, oil firing possessed certain attractions that made it popular. Apart from the psychological advantages of knowing and controlling one's fuel supplies, there were certain technical advantages. In the first place, the operator was relieved of any trouble in respect of the removal of ashes. Secondly, oil fuel tended to operational economy as it was very easy to turn off the tap when the heat was not required. Thirdly, oil firing had an advantage over many other forms of heating in that it was possible to pump in the heat rapidly—to put this in rather non-technical language—when one wanted to. This flexibility was certainly valuable.

Furnace installations to use oil fuel, because of their simplicity, could be relatively small in dimensions and also relatively cheap. Furthermore, maintenance was a reasonably straightforward matter provided the furnaces were suitably designed. He therefore desired to endorse what other speakers had said, and stress the importance of designing furnaces specially for use with oil fuel. Those furnaces he had seen where the consumption had been lowest and the throughput highest were furnaces of the inflame type, designed with particular care to ensure that the heat generated at the burners impinged directly on to the metal. By making the furnaces snug there was little chance of the flames escaping contact with the metal, thus minimizing the loss of useful heat into the stack.

In the fabrication of light alloys the problem was a little more difficult as it was not reasonable to expose light alloys to direct contact with the flames. This involved the designing of suitable muffle furnaces to operate at temperatures round about 500°C., and he felt this problem had not yet been adequately tackled. There was ample room for co-operation between the fuel oil expert and the furnace builders to produce something which would be economical in fuel, convenient to operate and, at the same time, would not entail excessive maintenance of the furnace by reason of uncontrolled impact of the flames on the refractories.

He had looked up some cost figures relating to the non-ferrous industry, these being for the year 1944. Based on these figures it seemed to him that oil was overtaking coal, even at that date. For what they were worth, the figures showed that the cost of reheating brass with coal firing was 6s. 6d. per unit and only 7s. 3d. if fuel oil was employed. When melting brass the most favourable conditions were those found in the low frequency induction electric furnace. On the 1944 figures, which he gave, again, for what they were worth, the relative costs were 13s. per ton for low frequency electric heating, 16s. 9d. for coal firing and 20s. for fuel oil. Possibly these figures had come closer together during the last two years.

Mr. G. VIVIAN DAVIES said that there was one point which was of great importance in the conversion to oil, and that was that in various industries a variety of different coals commonly had to be used. For example, one grade of coal was used for the initial firing, another grade to get up to maintenance temperature and so on, and in some cases it was necessary to use three or four different grades of coal. The separation and segregation of those coals was not an easy process, and if they could be replaced by one fuel only a distinct advantage would be achieved. This was certainly an operative feature of some of the ceramic industries though not in others.

Mr. G. J. GOLLIN said that it was very useful to have had, in the course of that discussion, a short resumé on the application of oil fuel to locomotives. The application of oil for this purpose, bearing in mind that here was a combustion chamber built essentially around a rectangular grate and not evolved for the use of liquid fuel, had accentuated the arguments put forward by the authors of the paper. It was evident that, owing to ease of control, it might be possible to have coal fired locomotives converted to oil fuel to enable one therm of oil to do the work of 1.1 or 1.2 therms of solid fuel. He had no figures which indicated a very much higher thermal ratio. In this conversion programme, the Railways were going to burn thousands of tons of oil. The authors of the paper had indicated, however, that if the application were chosen carefully it should be possible not

only to save weight of fuel (that did not matter at all), but, what was more important in the national interest, to make one therm of liquid fuel do more than was done before with one therm of solid fuel.

One speaker had advised the use of the paint spray if there was difficulty in getting an oil burner. Many of the early oil burners were designed to operate on the paint spray principle. This, however, had two defects. First of all, with every pound of oil, one burned about 15-18 lbs. of air. An oil burner, therefore, should be chosen that looked after the air—that was very important. One had to bring in the air at the right velocity and mix it thoroughly with the fuel ; it was not only the atomizing of the oil that counted. Secondly, the paint spray might not atomize to the degree of fineness required for combustion or to the degree of uniformity which was necessary. It was desirable, so far as possible, to avoid getting some big and some small drops. Uniformity was to be sought after. Therefore, the burner should be able to deliver a fine atmosphere of even-sized particles.

In concluding the proceedings, the CHAIRMAN expressed the thanks of the Conference to the authors of the paper and to those who had contributed to the discussion.

Section F—Special Industrial Sessions

This section opened with a session on The Light and Heavy Clay Industries, an application in which oil fuel has considerable scope. Mr. M. RODDAN and Mr. T. C. BAILEY made the following contributions to the general discussion :—

Mr. RODDAN said : " It is generally accepted that the clay industry is in the process of a change over from the intermittent to the continuous method of firing, and the reasons for this have been made clear by the papers presented to-day. It has also been indicated that, for practical considerations, the change over must be a gradual one over a period of years.

" One of the major advantages of the continuous process is that the heat expended per unit of ware fired is very much reduced—taking Mr. Stannier's figures—to somewhere about one-quarter to one-eighth of that required with hand fired coal on an intermittent kiln. This saving is, however, only possible by using some form of controlled heat, which permits of considerable reduction in the time of firing by virtue of accurate and steady control of the rate of temperature rise throughout the firing period.

" On an intermittent kiln, hand stoked, the temperature at any point in the kiln rises in a series of waves having the same periodicity as the intervals of firing. It is the rate of temperature rise during the time of maximum heat release from the fire that must be controlled to prevent damage to the ware and, therefore, when a controlled fuel, such as oil, is used the waves in the temperature curve do not occur and the average rate of temperature rise can be the same as that obtained during the short period of maximum heat release with solid fuel. This would give a very much shorter time cycle with a corresponding reduction in fuel consumption.

" From records of conversions of this type of kiln to oil in this country and abroad, it appears that the thermal input is only about half that on hand fired solid fuel and, on this basis, each ton of oil would replace about 3 tons of coal.

" The continuous kiln is the ultimate aim, and oil can be applied very satisfactorily to this type of kiln, but the change over will take years and, in the meantime, it seems that some worth while economy would be effected by converting existing kilns to oil. The national interest would be better served by using one ton of oil to replace 3 tons of coal on intermittent kilns than to replace 1½ tons of coal on boiler firing.

" From the consumer's view point, at to-day's prices for oil in the Potteries, coal would have to be delivered at about 42/- per ton to equal oil on the above assumption without making any allowance for saving of labour in stoking. Further, the reduced firing period would automatically increase the output capacity of the kilns."

Mr. BAILEY said : " I was very pleased to hear the references to the use of oil fuel made by several speakers. It is, however, to be hoped that oil will not be used indiscriminately, but confined to those sections of the clay industry where it will show the greatest technical efficiency and replace the most coal. It would appear that biscuit firing in the pottery industry and the manufacture of high temperature refractories are the sections of your industry where oil would present the greatest advantages—the manufacture of common building bricks is probably not the best field for using oil.

" Mention has also been made of the friendly co-operation of the gas and electricity undertakings in the development of efficient kilns. The oil industry is also ready to collaborate with other fuel suppliers and manufacturers of kilns and equipment, and is only too anxious to secure, wherever possible, the best design of kiln, so using fuel to the maximum efficiency."

The second of the special industrial sessions concerned The Railways. One of the subjects discussed was the design and operation of locomotives in relation to fuel efficiency. In this connection, the conversion to oil of some twelve hundred locomotives for use in Great Britain was of considerable interest, and written contributions on this aspect from Mr. G. J. GOLLIN and Mr. R. M. MACFARLANE are given below :—

Mr. GOLLIN says : " Conversion of a locomotive designed for solid fuel to the use of liquid fuel will produce results which will satisfy performance requirements and a fair standard of efficiency. One therm from the oil can at least be made to do what one therm from the coal did before conversion.

" In spite of the above it should be realized by railway engineers that the general quality of combustion efficiency possible in such a conversion bears poor comparison with that obtainable from the standard industrial and maritime oil burning gear of to-day. Here burners and air control are designed to give intimate mixing of fuel and air with rapid and complete combustion. The locomotive designed for solid fuel, both in regard to the shape of the combustion chamber and space available for the application of the burner gear, makes it difficult to emulate the very successful results obtained in numerous industrial applications of liquid fuel, wherein it is not uncommon for one therm from liquid fuel to do the work previously done by one and a half therms from alternative fuels."

Mr. MACFARLANE says : " Mr. Dymond, in his excellent paper, briefly mentions that a steam locomotive fired with liquid fuel will give an improved performance as compared with the normal solid fuel. It should be borne in mind that still greater advantages can be looked for from the use of liquid fuel because the oil burning gear and its application can be considerably improved whereas it is difficult to see where any drastic improvement can be made in the existing method of handling solid fuel. However, as with solid fuel, to get the fullest advantage from liquid fuel, careful planning is required both as regards the method of burning and traffic operation.

" The correct technique must be adopted for each type of traffic, particularly in the case of mineral, freight, branch and suburban passenger traffic, in which categories the majority of the engines are used.

" In addition to applying the principles of oil firing correctly and operating the railway in such a way as to take advantage of its special features, it is essential that the equipment be correctly installed and the control gear be of such a type that the operators can manipulate it to get the best results. Such operators must, of course, be trained to enable them to appreciate the totally different conditions required for burning a liquid fuel as compared to any previous experience on coal firing. The men responsible for the maintenance of the gear must also appreciate what is required of it in action.

" As an instance of what can be achieved by paying attention to the points indicated above, a foreign railway using oil firing extensively for its locomotives has effected a reduction in its overall oil consumption of approximately 8%.

" Mention has been made of the difficulties that are accumulating due to the deterioration in the quality of solid fuel. The conversion to liquid fuel offers an immediate remedy and, if attention is paid to the points mentioned above, then oil fuel can be consumed so as to give improved performance and satisfactory efficiency."

Finally, one subject of interest concerning the use of fuel oil for the dustproofing of coal was brought to the attention of the third of the special industrial sessions on The Coal Industry in a written contribution by Mr. J. S. WILDING.

Mr. WILDING says : " A good deal of experimental work was carried out in this country before the war on the dustproofing of coal with oil, and it is felt that the attention of this session might be drawn to this special method of preparation of coal for the market.

" The use of dustproofed coal has been established in the U.S.A. for many years. Whilst no commercial plant yet exists in this country to my knowledge, some promising investigations have been carried out, notably by the Fuel Research Station and the Combustion Appliance Makers' Association. Prior to the outbreak of war, certain industrial concerns were, in fact, considering the erection of the necessary plant for dustproofing on a commercial scale.

" Dustproofing is accomplished by spraying coal with a petroleum oil—a medium viscosity fuel oil has so far given the best results—to the extent of five to fifteen pounds (approx. $\frac{1}{2}$ to $1\frac{1}{2}$ gallons) of oil per ton of coal, according to the rank and size of the coal treated. The dust and fines are thereby made to adhere to the larger coal sizes, giving a clean dust-free fuel. The nuisance and losses caused by flying dust are eliminated and segregation of the fines is largely suppressed.

" The process is specially applicable to coals for domestic use and central heating, and for concerns such as paper mills and food factories where the presence of flying dust may injure the product."

Section G — Modern Heating and the Architect

Section H — The Home and its Fuel Services

The remaining sessions of the conference were devoted to fuel saving in the domestic sphere. The subject of domestic heating by means of liquid fuels, among which are included kerosine, liquid gas and fuel oils, is the particular concern of the Liquid Fuel Installations Committee of the Institute, whose report to the Minister of Fuel and Power is now in an advanged stage of preparation. It was, therefore, considered opportune that some short account of the Committee's work should be given at these two sessions and, accordingly, the following contributions were submitted by Mr. G. RICHARDSON to Section G, and Mr. J. S. JACKSON to Section H.

Mr. RICHARDSON (in a written contribution) says : " There are three points I would like to make :—

" 1. In reply to a previous point in Session I, Mr. Bernard gave as an excuse for the low thermal efficiency of electricity generating stations the fact that the coal used is of very poor quality and would be virtually unusable for other purposes. While admitting this fact to be true, I would point out that it is a quite invalid reason to put forward. The efficiency of heat transfer in the boilers of a generating station is of an exceptionally high order, frequently as high as 80% despite the quality of the fuel, and is one which is rarely achieved in any other form of coal combustion. Where the *in*efficiency lies is in the use made of the steam produced from that so-called unusable coal, i.e., in the generating plant, which in the best conditions uses something usually less than 40% of the heat available in the steam

and rejects the remainder to the cooling water. It is this wasted heat that the protagonists of thermal-electric stations for district heating and power supplies wish to be used, but it would involve a change in policy rather than an improvement in existing methods. It is, in my view, a matter for some regret that there should have been so much apparent resistance to the installation of plant that would make it possible for this waste heat to be used. While the change would admittedly be difficult in existing generating stations, there is surely some ground for expecting that the policy adopted in siting and equipping new generating stations should pay some regard to the possibility of developments in this direction.

" 2. I have noted with some misgiving the very small mention made in this session of rural housing as opposed to urban housing. Though the latter far outweighs the former quantitatively, it is generally agreed that rural housing has an importance greater than the mere size of the problem would warrant, and there is no doubt that the social consequences of its neglect would be far-reaching. It should be realized too that rural housing authorities have a difficult task in erecting houses to the standards of amenity established for towns, where gas and electricity services are readily available.

" It may be deduced from the results of the Heating of Dwellings Inquiry, published in the Egerton Report*, that something over 80% of all rural dwellings have in the past been fitted with coal fired cooking ranges. It may also be seen that whereas 29% of the older housewives prefer coal for cooking, only 12% of the younger ones do so. Furthermore, the Inquiry shows that half of the coal fired ranges that are fitted are supplemented or displaced by another cooking appliance using some other fuel. I would suggest that these indications, if substantiated, would justify a review of our former policy in planning and equipping rural houses. Shall we not, in fact, tie up uselessly a great deal of much-needed capital if practically all rural houses are fitted with combination ranges, without due regard to the availability of other fuels? Moreover, are we not expecting rather too much of designers in asking for an appliance using solid fuel, the most intractable of all fuels, to do three jobs, cooking, space heating and water heating, equally well at the same time? It is interesting to note that some of the recent lay-outs suggested for rural dwellings based on solid fuel insist on two fires to perform these three functions adequately.

" There is one other aspect of this problem. Within the limits imposed by present or proposed methods of space heating in the small dwelling, there is not an unlimited number of ways of planning a ground floor of 450 sq. ft. The three type plans on pages 34, 36 and 38 of the Design of Dwellings Report (*H.M.S.O.*) show the generally accepted methods—the dining-kitchen type, the working kitchen type and the kitchen living-room type. Cooking, water heating and space heating facilities are provided in the third type of plan by a coal fired combination range in the living-room. This necessitates a division of the culinary processes between the living-room and the scullery—not a very convenient arrangement. The particular defect of this plan to which I wish to draw attention, however, is that it is physically impossible properly to accommodate any additional cooking appliance. So that, no matter what other fuel is, or may become, available in a particular area as an alternative to cooking by solid fuel, people living in houses built to this plan will have the utmost difficulty in taking advantage of it. I, therefore, wish to make a mild protest against the recommendation in the Design of Dwellings Report that the third, or kitchen living-room type of plan, is the most suitable for rural housing, and to deprecate a too rigid adherence to this suggestion. I would point out that the first alternative, the dining-kitchen type, can accommodate a combination range, if necessary, and at the same time provide space for an alternative cooking appliance.

" 3. Finally, perhaps we may pause to consider what the alternatives to solid fuel for cooking are in rural areas. The Simon Report† does not envisage any great expansion in the areas served by gas mains. While rural electrification will undoubtedly continue, it still has a long way to go and much leeway to make up. It must also be remembered that, for cooking and water heating purposes, a two-part

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* Post-War Building Study No. 19—" Heating and Ventilation."

† Domestic Fuel Policy, H.M.S.O., Cond. 6762.

tariff with a unit charge much in excess of ¾d may make electricity rather expensive for the man of small means. The remaining alternatives are fuels which have received little mention in this section, namely kerosine (paraffin oil) and butane (liquid or bottled gas). In relation to the total heat demands of the country, it is quite true, as Mr. Gaitskill said in Session I, that neither of these fuels makes a significant contribution, but it is equally true that in rural areas practically a fifth of all households use one or the other for cooking purposes. These fuels can, and do, make a considerable contribution towards raising the standard of convenience in rural dwellings and are available virtually everywhere.

"I cannot here give any adequate account of the recent developments in appliance design. The Institute of Petroleum is preparing a report for the Minister of Fuel and Power on 'Liquid Fuel Installations in Buildings' which will deal very fully with the use of both these fuels in small dwellings. Some account also has been given elsewhere in this Conference. Suffice it to say now that, accelerated by war demands, there have been very considerable developments which include :—

(a) the improvement of wickless burners so that they do not smoke or smell and can be left in continuous operation for weeks on end ;

(b) the operation of such burners by thermostatic controls ;

(c) radiant elements for space heaters that convert a good part of the output into high temperature radiation ;

(d) generally much improved standards of construction and design.

There is now no need for rural housing authorities to resign themselves to a lower standard of amenity than their counterparts in urban areas simply because town gas and electricity are not available. Whether as a short or long term measure, I would suggest that the possibility of using kerosine and butane for cooking, lighting and water heating, in particular, should be thoroughly investigated."

Mr. JACKSON said : "Two petroleum fuels are available for use in small dwellings, namely :—

1. Bottled gas (Butane).
2. Kerosine (Paraffin Oil).

"The consumption of bottled gas in this country is admittedly comparatively small, but it is anticipated that this will increase steadily. A full range of modern appliances, such as radiant space heaters, hotplates, cookers and geysers, is already on the market, and in rural areas where town gas is not available, butane provides a very convenient and attractive substitute. Incidentally, the export abroad of butane gas appliances is making a useful contribution to our export drive.

"As regards kerosine, there are one or two points which ought to be emphasized. In the first place, it is interesting to note that the consumption of kerosine in this country actually increased by as much as 50% during the period 1921-38. It is widely used in rural areas, and it is estimated that there are 2,500,000 kerosine space heaters and 1,000,000 kerosine cookers in use in the United Kingdom.

"The war created many special demands from which the following developments have emerged :—

1. The increased use of wickless burners of the short drum type incorporating incombustible kindlers.
2. The development of space heaters incorporating short drum burners fitted with radiant elements.
3. The development of thermostatically controlled water heating appliances operated by short drum burners.

"The following four illustrations show typical appliances which have been made possible by the above developments :—

FIGURE 1

" **Fig. 1** shows a space heater with a short drum wickless burner fitted with an incombustible kindler. This burner incorporates a radiant element capable of converting a substantial proportion of the available heat into radiant heat. The burner is controlled by a valve operating in three positions — high, low and off. Appliances of this kind are odourless in use, completely portable, will burn for long periods (months) without attention beyond replenishing the oil container and show an efficiency of virtually 100%.

" **Fig. 2** illustrates a simple form of water circulator operated by a thermostatically controlled kerosine burner. It is capable of providing hot water to meet the requirements of a normal small dwelling. An efficiency of the order of 80% is claimed for this appliance, which obviously offers many advantages over the more usual domestic water heater operated on solid fuel.

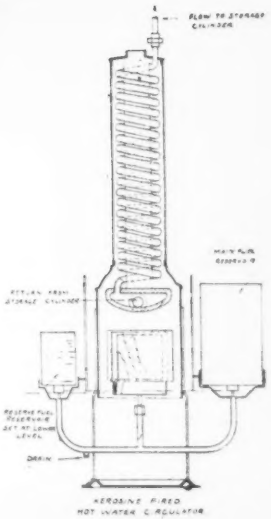
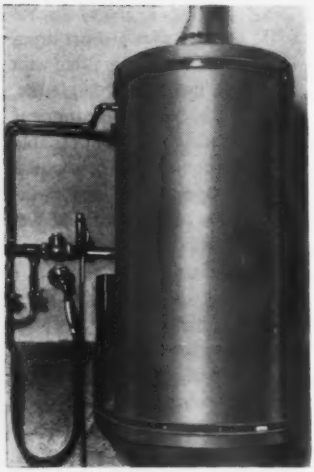
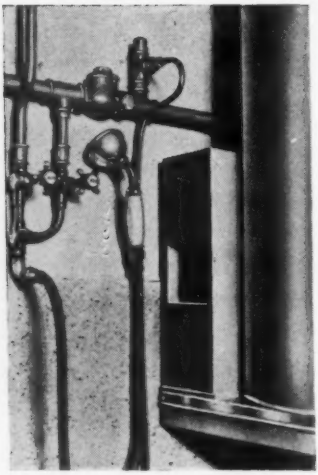


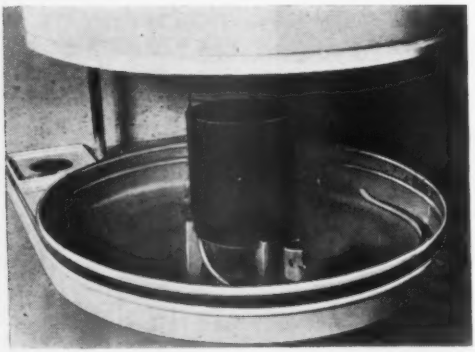
FIGURE 2



(a) View of complete hot water storage heater.



(b) View showing one of two fuel containers.



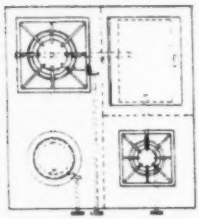
(c) View with base lowered showing burner.

FIGURE 3

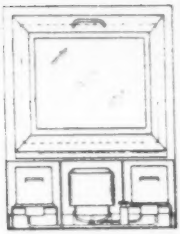
"**Fig. 3, (a), (b)** and **(c)**, shows a hot water storage system, again operated by a thermostatically controlled kerosine burner. The volume of hot water available varies according to the model—the smaller models provide 5 gallons, while the larger models provide 20 gallons or more.

"It will be appreciated that the devices shown in Figures 2 and 3 operate automatically for periods of several months and require no attention beyond the replenishing of the oil containers. As a development of these appliances, kerosine operated hot water systems can be produced to give trouble-free service, meeting the full requirements of any small dwelling.

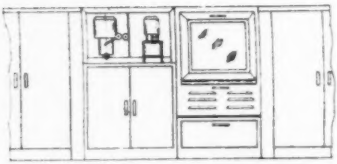
"**Fig. 4** shows a suggested modern type of kerosine operated cooker consisting of a hotplate unit and a separate oven unit, each operated by short drum burners of the type described above. It will be noted that the oven may be placed in either a medium or high position. It is suggested that these appliances should be dimensioned so that they may be inserted as units along with standard modern kitchen fittings.



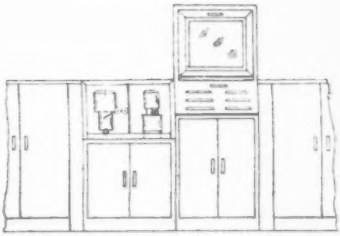
— PLAN VIEW OF HOTPLATE UNIT —



— FRONT ELEVATION OF OVEN UNIT —



— ARRGT OF LOW LEVEL HORIZONTAL COOKER —



— ARRGT OF HIGH LEVEL HORIZONTAL COOKER —

SUGGESTED METHOD OF UNIT CONSTRUCTION FOR KEROSINE OVEN AND HOTPLATE

FIGURE 4

" A considerable demand for bottled gas and kerosine undoubtedly exists, particularly in rural areas, and efforts have been, and are being, made to produce appliances operating on liquid gas and kerosine which will give service comparable with that obtainable with gas or electricity. Kerosine at present enjoys a distinct price advantage, and the fact that an adequate reserve may easily be stored under the user's control is also an attractive feature. Bottled gas is delivered under moderate pressure in steel bottles, and little further comment is called for in this connection. It is clean and convenient and may reasonably be described as an almost ideal fuel.

" In the past, the filling of containers with kerosine has sometimes led to spillage and consequent inconvenience. A piped system, feeding appliances directly from an outside storage tank, is therefore now recommended when kerosine is in regular use.

" Modern kerosine appliances are labour-saving, clean, and economical in use.

" A Post-War Building Study dealing with ' Liquid Fuel Installations ' is being prepared by the Institute of Petroleum. This will constitute a comprehensive survey of liquid fuels and the appliances available for their use. It is expected that publication will take place early in 1947."

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